

4

Urban, Agricultural, and Environmental Water Use

This chapter describes present and forecasted urban, agricultural, and environmental water use. The chapter is organized into three major sections, one for each category of water use.

Water use information is presented at the hydrologic region level of detail under normalized hydrologic conditions. Forecasted 2020-level urban and agricultural water use have not changed greatly since publication of Bulletin 160-93. Forecasted urban water use depends heavily on population forecasts. Although the DOF has updated its California population projections since the last Bulletin, U.S. census data are an important foundation for the projections, and a new census will not be performed until 2000. The Department's forecasts of agricultural water use change relatively slowly in the short-term because the corresponding changes in forecasted agricul-

Nursery products are California's third largest farm product in gross value. The nursery industry is affected by the availability of both agricultural and urban water supplies.

tural acreage are a small percentage of the State's total irrigated acreage. Changes in base year and forecasted environmental water use from the last Bulletin reflect implementation of SWRCB's Order WR 95-6 for the Bay-Delta.

Summary of Key Statistics

Shown below for quick reference are some key statistics presented in this chapter. Water use information values shown are for applied water use in average water year conditions. The details behind the statistics are discussed later.

	1995	2020	Change
Population (million)	32.1	47.5	+15.4
Irrigated crops (million acres)	9.5	9.2	-0.3
Urban water use (maf)	8.8	12.0	+3.2
Agricultural water use (maf)	33.8	31.5	-2.3
Environmental water use (maf)	36.9	37.0	+0.1
<i>Percent of total</i>			
Urban water use (%)	11	15	+4
Agricultural water use (%)	43	39	-4
Environmental water use (%)	46	46	0

Water Use Calculation

The urban, agricultural, and environmental water uses calculated in this chapter are combined with water supply information (Chapter 3) to form statewide balances (Chapter 6) and regional balances (Chapters 7-9). As noted in the Chapter 3 discussion of water supplies, Bulletin 160-98 water balances are computed with applied water data, instead of the net water data used in previous editions of the Bulletin.

Figure 4-1 shows statewide water use in terms of applied water and depletions. The two methods provide similar results at a statewide level. (The large depletion associated with environmental water use reflects the magnitude of wild and scenic river outflow to the Pacific Ocean, as discussed later in the chapter.)

For purposes of presentation in the Bulletin, urban, agricultural, and environmental water uses are treated separately. In reality, these uses are usually linked by California's hydrologic system. As discussed in Chapter 3, the return flow from one water user often becomes the supply for a downstream user. The applied water budgets used in Bulletin 160-98 reflect the multiple uses of water in a river basin. Water supplies in a river basin may count toward meeting wild and scenic river use in the Sierra Nevada foothills, count toward urban and/or agricultural uses on the Central Valley floor, and count toward meeting Bay-Delta outflow farther downstream.

Another change from Bulletin 160-93 was eliminating the "other" water use category to simplify information presentation. This category included ma-

jor canal conveyance losses, recreation use, cooling water use, energy recovery use, and use by high water using industries. Water uses previously categorized as "other" are now included in urban, agricultural, or environmental water use, according to their intended purpose. At a statewide level, the magnitude of these other uses is small in comparison to that of the major categories.

Land Use Considerations

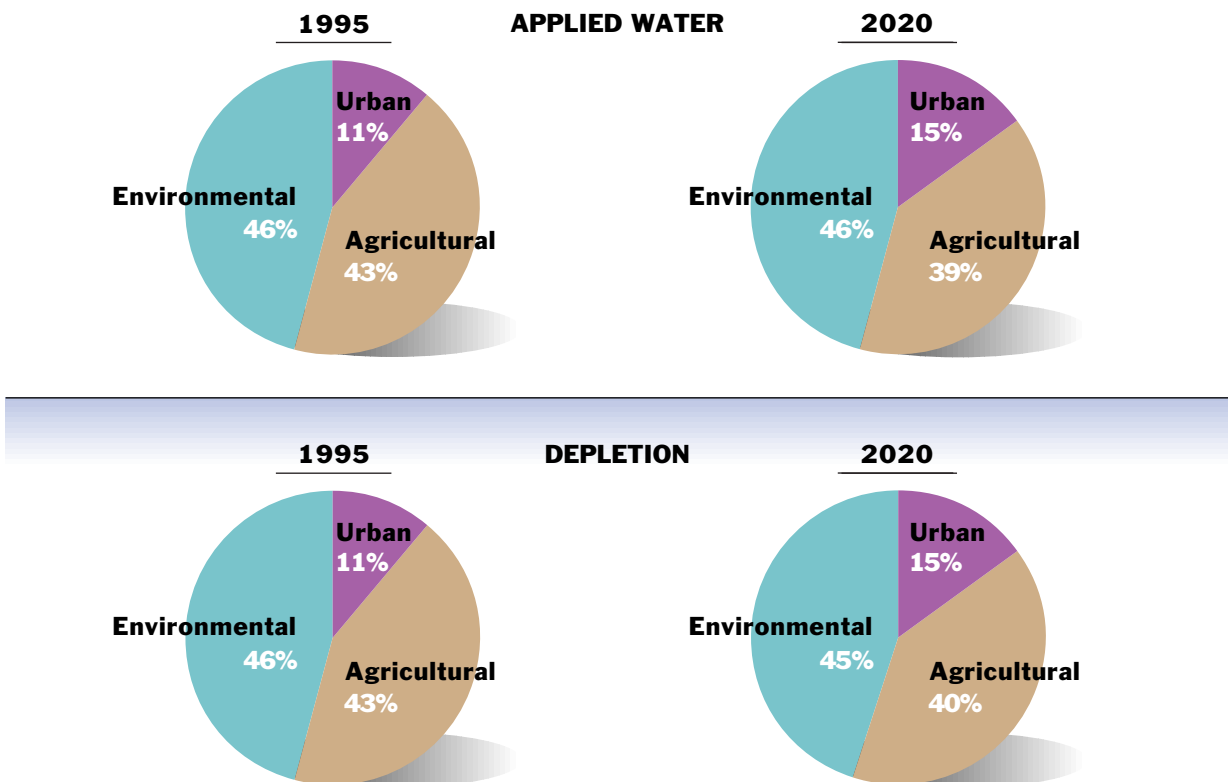
It is important to understand how urban, agricultural, and environmental water use are shaped by land use patterns and land use planning. Patterns of future development and water use trends are dictated by city and county land use planning decisions. Urbanization of agricultural lands, open space preservation, habitat creation, and wetlands preservation policies are examples of land use-related decisions that have water use implications.

DOF forecasts that California's population will increase by more than 15 million people by 2020. Where these additional people live affects statewide urban water use. For example, in terms of percent population increase, DOF forecasts that the City and County of San Francisco will have one of the slowest growth rates statewide. Adjoining Bay Area counties are also forecasted to grow slowly, reflecting the region's intensive urbanization and relatively small amounts of remaining undeveloped land. Areas expected to experience high growth rates include some San Joaquin Valley counties and the Inland Empire region in South-



Future land use patterns are important in forecasting future water use. How and where presently undeveloped lands are developed—or are preserved from development—affects water use calculations.

FIGURE 4-1
California Applied Water Use and Depletion



ern California. This population shift to warmer, drier inland areas where urban outdoor water use is higher affects future statewide water demands.

The location of urban development also affects agricultural water use. For example, subdivisions constructed on non-irrigated grazing lands do not directly displace agricultural use (although they may compete with existing agricultural water users for a supply). Subdivisions constructed on irrigated farmland result in direct conversion of water use from agricultural to urban. Bulletin 160-98 forecasts a statewide decline in irrigated acreage by 2020. Most of that decline is the result of expected urbanization of irrigated agricultural lands, especially in the San Joaquin Valley and South Coast areas. (To some extent, urbanization may shift agricultural development to presently undeveloped lands, but such lands are usually of lower quality and can economically support only limited crop types.) Local open space preservation goals can affect the extent of land use conversion. Williamson Act contracts are a commonly used means of encouraging preservation of agricultural land use, especially for agricultural lands near urban areas. Not all open space preservation goals affect water use. For example, some land use planning agencies in urban areas have set aside ridgetop areas as lands to be managed for recreation or open space to preserve viewsheds. If the areas set aside are non-irrigated grazing lands, water use impacts are minimal.

Policies to preserve and enhance wetlands can entail creating new wetlands or providing increased water supplies to existing wetlands, thus increasing environmental water use, often by conversion of agricultural water supplies. Programs creating new wildlife habitat areas would entail conversion of agricultural lands and water supplies to environmental uses.

Urban Water Use

Forecasts of urban water use for the Bulletin are based on population information and per capita water use estimates, as described later in this section. Factors influencing per capita water use include expected demand reduction due to implementation of water conservation programs. The Department has modeled effects of conservation measures and socioeconomic changes on per capita use in 20 major water service areas to estimate future changes in per capita use by hydrologic region.

The Department's Bulletin 160 series makes per

capita water use estimates at a statewide level of detail. An urban water agency making estimates for its own service area would be able to incorporate more complexity in its forecasting because the scope of its effort is narrow. For this reason, and because DOF population projections seldom exactly match population projections prepared by cities and counties, the Bulletin's water use forecasts are expected to be representative of, rather than identical to, those of local water agencies.

Population Growth

Data about California's population—its geographic distribution and projections of future population and their distribution—come from several sources. The Department works with base year and projected year population information developed by DOF for each county in the State. The decadal census is a major benchmark for population projections. DOF works from census data to calculate the State's population in noncensus years, and to project future populations. Figure 4-2 shows DOF's projected growth rates by county for year 2020. (State policy requires that all State agencies use DOF population projections for planning, funding, and policy making activities.)

DOF uses as its starting population the 1990 census, modified by the Bureau of the Census for known misreporting. (These counts represent a modification to the age distribution of the census count and not an adjustment for undercount to the total.) Between 1950 and 1980 the birthrate in California mirrored the nation's. A sharp divergence began during the 1980s; the nation's birthrate was flat while the birthrate in California rose sharply.

California's annual growth rate was 2 to 3 percent throughout the 1980s. After 1990, the rate slowed to 1.3 percent and the State's population grew by only 2 million, for a 1995 population of 32.1 million. California's growth since 1992 has also been affected by lower than projected natural increase (births minus deaths) and net migration. Domestic migration patterns tend to parallel the unemployment differential rate between California and other states. Between 1990 and 1994, California lost more than 700,000 jobs due to the economic recession. This job loss resulted in a new demographic phenomenon for California—a net migration of California residents to other states. By 1996, California had replaced the jobs lost during the recession.

Migration is the most volatile component of

FIGURE 4-2
Projected Growth Rates by County, 1995-2020

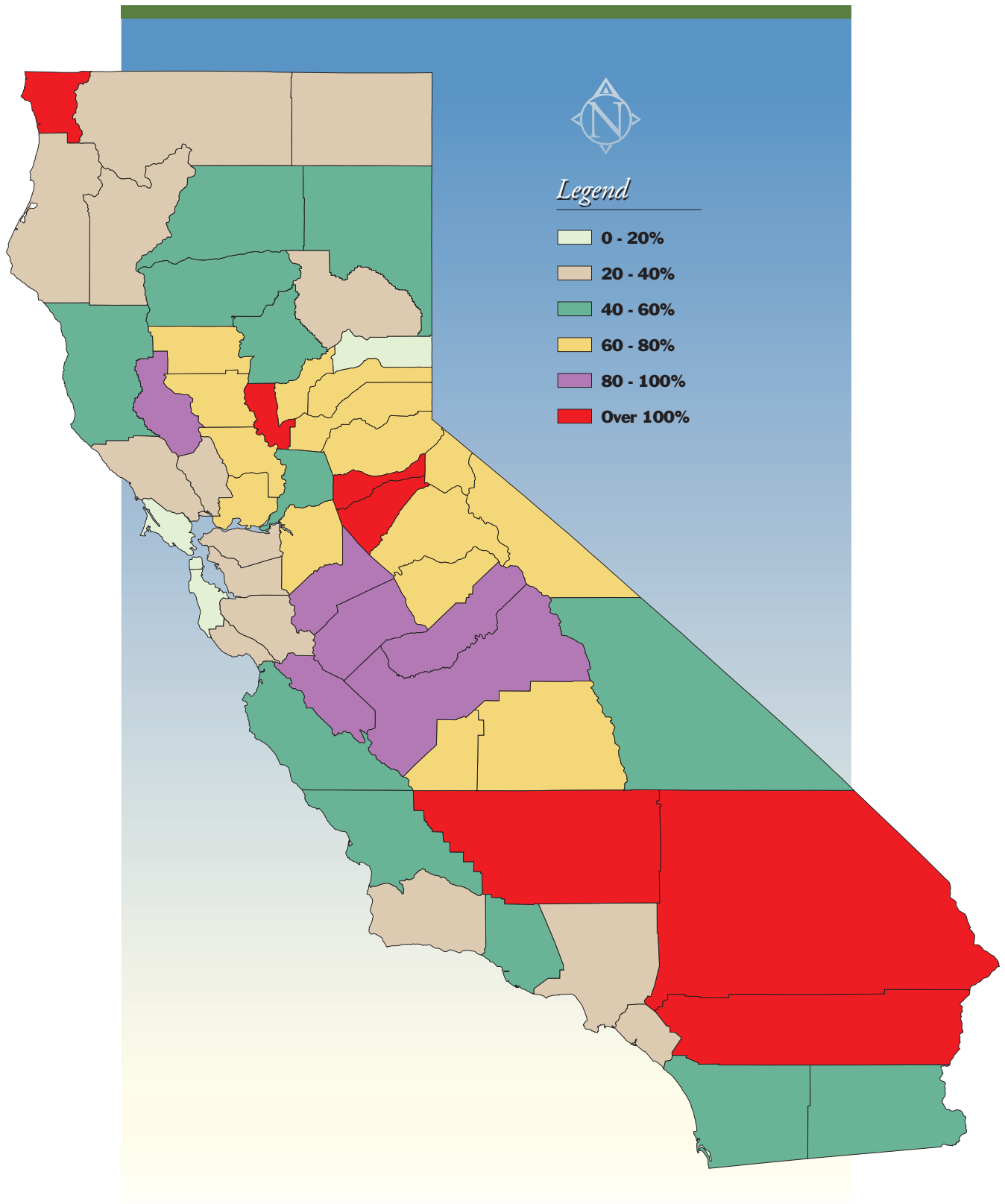
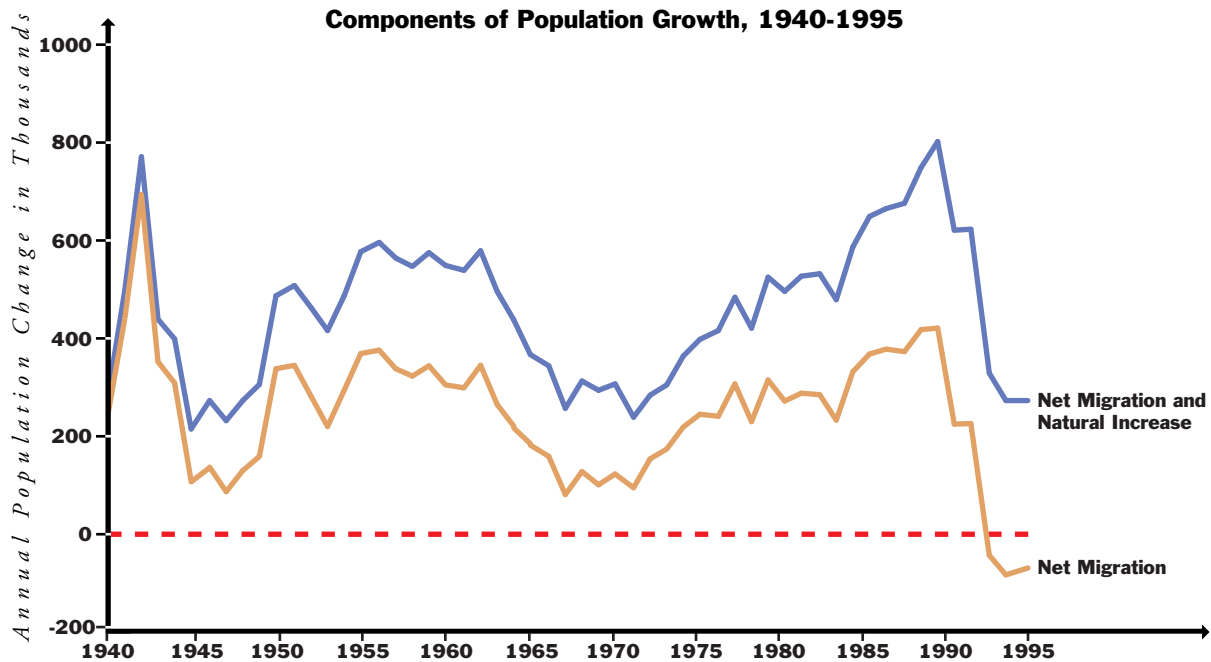


FIGURE 4-3



Urban water demand forecasts are driven by the expected increase in California's population—more than 15 million new residents by 2020. Multipurpose reservoirs help meet needs for water-based recreational opportunities, especially in arid Southern California.

population change. Migrants are separated into two categories: domestic (from other states) or foreign (from other countries). Since 1980, approximately 30 percent of net migration has been domestic and 70 percent foreign. DOF attributes fluctuations in migration primarily to domestic migration, since undocumented migration has been fairly constant and legal foreign migration has slowly increased. Figure 4-3 shows natural increase and net migration for the years 1940-95.

DOF uses a baseline cohort-component method to project population by gender, race/ethnicity, and age. A baseline projection assumes people have the right to migrate where they choose and no major natural catastrophes or wars will occur. A cohort-component method traces people born in a given year throughout their lives. As each year passes, cohorts change due to mortality and migration assumptions. New cohorts are formed by applying birthrate assumptions to women of childbearing age. Special populations display different demographic behavior and other characteristics and must be projected separately. The primary sources of special populations are prisons, colleges, and military installations.

Population projections used in Bulletin 160-98 are based on DOF's *Interim County Population Projections* (April 1997). Table 4-1 shows the 1995 through 2020 population figures for Bulletin 160-98 by hydrologic

TABLE 4-1

**California Population by Hydrologic Region
(in thousands)**

<i>Region</i>	<i>1995</i>	<i>2020</i>
North Coast	606	835
San Francisco Bay	5,780	7,025
Central Coast	1,347	1,946
South Coast	17,299	24,327
Sacramento River	2,372	3,813
San Joaquin River	1,592	3,025
Tulare Lake	1,738	3,296
North Lahontan	84	125
South Lahontan	713	2,019
Colorado River	533	1,096
Total (rounded)	32,060	47,510

region. DOF periodically updates its population forecasts to respond to changing conditions. Its 2020 population forecast used for Bulletin 160-93 was 1.4 million higher than the 2020 forecast used in Bulletin 160-98. The latter forecast incorporated the effects of the recession of the early 1990s. Small fluctuations in the forecast do not obscure the overall trend—an increase in population on the order of 50 percent.

The Department apportioned county population data to Bulletin 160 study areas based on watershed or water district boundaries. Factors considered in distributing the data to Bulletin 160 study areas included population projections prepared by cities, counties, and local councils of governments, which typically incorporate expected future development from city and county general plans. The local agency projections indicate which areas within a county are expected to experience growth and provide guidance in allocating DOF's projection for an entire county into smaller Bulletin 160 study areas. Table 4-2 compares DOF interim projections with councils of governments projections.

Factors Affecting Urban Per Capita Water Use

Urban per capita water use includes residential, commercial, industrial, and institutional uses of water. Each of these categories can be examined at a greater level of detail. Residential water use, for example, includes interior and exterior (e.g., landscaping) water use. Forecasts of urban water use for an individual community may be separated into components and forecasted individually. It is not possible to use this level of detail for each community in the State in Bulletin 160-98. Bulletin 160-98 modeled components of urban use for representative urban water agencies in each of the State's ten hydrologic regions and extrapolated those results to the remainder of each hydrologic region, as described later in the chapter.

Demand reduction achieved by implementing water conservation measures is important in forecasting per capita water use. Bulletin 160-98 incorporates demand reductions from implementation of urban best management practices contained in the 1991 *Memorandum of Understanding Regarding Urban Water Conservation in California*. Bulletin 160-98 assumes implementation of the urban MOU's BMPs by 2020, resulting in a demand reduction of about 1.5 maf over the year 2020 demand forecast without BMP implementation. The following subsections detail existing urban water conservation programs and estimated demand reductions. For simplicity of presentation, conservation plans required of USBR water contractors are described in the agricultural water conservation section, since agricultural water supply comprises the majority of CVP water contracts. USBR's urban water contractors are also required to comply with these requirements.

The relationship of water pricing to water consumption, and the role of pricing in achieving water conservation, has been a subject of discussion in recent years. Elected board members of public water

TABLE 4-2

**Comparison Between Department of Finance and Councils of Governments Population Projections
(in thousands)**

	<i>1990 Census</i>	<i>2010 Projections^a</i>	
		<i>DOF</i>	<i>COG</i>
Southern California Counties	17,139	23,352	24,038
Bay Area Counties	6,020	7,489	7,540
Central Coast Counties	1,172	1,508	1,518
Greater Sacramento Counties	1,684	2,542	2,586
San Joaquin Valley Counties	2,742	4,608	4,641

^a COG data were only available for 2010, thus 2010 COG forecasts are compared with DOF 2010 forecasts.

Landscape Water Use

The Model Water Efficient Landscape Ordinance was added to Title 23 of the California Code of Regulations in response to requirements of the 1990 Water Conservation in Landscaping Act. Local agencies that did not adopt their own ordinances by January 1993 were required to begin enforcement of the model ordinance as of that date.

The model ordinance applies to all new and rehabilitated landscaping (more than 2,500 square feet in size) for public agency projects and private development projects that require a local agency permit, and to developer-installed landscaping for single-family and multifamily residential projects. The

purpose of the ordinance was to promote water efficient landscape design, installation, and maintenance. The general approach of the ordinance was to use $0.8 ET_0$ as a water use goal for new and renovated landscapes. (ET_0 is a reference evapotranspiration, established according to specific criteria.) Tools to help meet that goal include proper landscape and irrigation system design.

To date, there has been no statewide-level review of how cities and counties are implementing this requirement; thus, its water savings potential remains to be quantified.

agencies ultimately have the responsibility for balancing desires to achieve demand reduction through water pricing with desires to provide affordable water rates to consumers. Urban water rates in California vary widely and are affected by factors such as geographic location, source of supply, and type of water treatment provided. Water rates are set by local agencies to recover costs of providing water service and are highly site-specific. Appendix 4A provides background information on urban water pricing. As described in the appendix's summary of price elasticity studies for urban water use, residential water demand is inelastic in most cases—water users were relatively insensitive to changes in price, for the price ranges evaluated. Water price plays a small role in relation to other factors affecting water use, such as public education and plumbing retrofit programs.

Urban Water Conservation Actions. State and federal legislation imposed standards to improve the water use efficiency of plumbing fixtures, requiring that fixtures manufactured, sold, or installed after specified dates meet the targets shown in Table 4-3. These requirements apply to new construction or to retrofitting existing plumbing fixtures, but do not require removal and replacement of existing fixtures. One water conservation action being taken by urban water agencies is to sponsor programs for voluntary retrofitting of fixtures, to accelerate demand reductions. (This action is one of the BMPs included in the urban MOU.) Some water purveyors, such as the City and County of San Francisco, have regulations requiring retrofit when homes are sold.

More than 200 urban water suppliers have signed the urban MOU and are now members of the California Urban Water Conservation Council. Some key points from the MOU are highlighted in the sidebar. Water suppliers signing the urban MOU committed

to implement BMPs unless a cost-benefit analysis conducted according to CUWCC guidelines showed individual BMPs not to be cost-effective, or unless there was a legal barrier to implementation. The MOU also committed CUWCC to study measures that could be added as new BMPs, such as establishing efficiency standards for water-using appliances.

The urban use forecasts in Bulletin 160-98 assume that water users statewide will implement BMPs by 2020, as set forth in Exhibit 1 of the MOU, whether or not the BMPs are cost-effective from a water supply standpoint. In making this assumption, the Bulletin recognizes that water conservation measures have potential benefits in addition to water supply, such as reduced water and wastewater treatment costs, other water quality improvements, reduced entrainment of fish at urban points of diversion, and greater control of temperature and timing of wastewater discharges. The Department believes this assumption is reasonable, given that funding sources for non-water supply benefits could help support BMP implementation, and that the planning horizon over which the Bulletin assumes that BMPs would be implemented (from 1995 to 2020) provides more time for implementation than does the MOU. The widespread acceptance that the existing BMPs have achieved, as evidenced by the number of MOU signatories, indicates that the BMPs are generally considered to be technologically feasible, so technology should not be a limiting factor in implementation.

Quantifying demand reduction from implementation of some BMPs is difficult (for example, public information programs and water education in schools). These actions contribute to implementation of other BMPs, such as demand reduction from installing water meters, but do not by themselves save quantifiable amounts of water. CUWCC reviewed implementation

TABLE 4-3
Summary of California and Federal Plumbing Fixture Requirements

<i>Plumbing Device</i>	<i>California (covers sale and installation)</i>	<i>Effective Date</i>	<i>Energy Policy Act of 1992 (covers only manufacture)</i>
Showerheads	2.5 gpm	CA 3/20/92 US 1/1/94	2.5 gpm
Lavatory Faucets ^a	2.75 gpm 2.2 gpm	CA 12/22/78 CA 3/20/92 US 1/1/94	2.5 gpm
Sink Faucets ^a	2.2 gpm	CA 3/20/92 US 1/1/94	2.5 gpm
Metering (self-closing) Faucets ^b (public restrooms)	hot water maximum flow rates range from 0.25 to 0.75 gallons/ cycle and/or from 0.5 gpm to 2.5 gpm, depending on controls and hot water system	CA 7/1/92 US 1/1/94	0.25 gallons/cycle (maximum water delivery per cycle)
Tub Spout Diverter ^a	0.1 (new), to 0.3 gpm (after 15,000 cycles of diverting)	CA 3/20/92	(does not appear to be included in EPA)
Toilets (residential)	1.6 gpf	CA 1/1/92 (new construction) CA 1/1/94 (all toilets for sale or installation) US 1/1/94 (non- commercial)	1.6 gpf
Flushometer valves ^a	1.6 gpf	CA 1/1/92 (new construction) CA 1/1/94 (all toilets) US 1/1/94 (commercial) US 1/1/97 (commercial)	3.5 gpf 1.6 gpf
Toilets (Commercial) ^a	1.6 gpf	CA 1/1/94 (all toilets for sale or installation) US 1/1/97	1.6 gpf
Urinals	1.0 gpf	CA 1/1/92 (new) CA 1/1/94 (all) US 1/1/94	1.0 gpf

^a California requirements are preexisting and more stringent than federal law; therefore California requirements prevail in California.

^b Federal law is more stringent than California requirements.



Local agencies were required by the 1990 Water Conservation in Landscaping Act to enforce ordinances intended to promote water-efficient designs. The act's requirements apply to landscapes greater than 2,500 sq. ft. in size.

and quantification of the initial BMPs, and developed a strategic plan in 1996 that included evaluating the BMPs and revising them to make them easier to quantify. The revised BMPs (see sidebar) were adopted by CUWCC in September 1997. The revisions included restructuring the original 16 BMPs to 14 BMPs (new BMPs were also added—rebate programs for high ef-

iciency washing machines and wholesale water agency assistance to retail water agencies), revising implementation schedules and coverage requirements, and adding new evaluation criteria. Implementation of some BMPs was extended beyond the original 10-year term of the existing MOU. Appendix 4B presents a synopsis of the revisions.

Urban Best Management Practices (1997 Revision)

BMP 1	Water Audit Programs for Single-Family Residential and Multifamily Residential Customers
BMP 2	Residential Plumbing Retrofit
BMP 3	System Water Audits, Leak Detection and Repair
BMP 4	Metering With Commodity Rates for All New Connections and Retrofit of Existing Connections
BMP 5	Large Landscape Conservation Programs and Incentives
BMP 6	High-Efficiency Washing Machine Rebate Programs (New)
BMP 7	Public Information Programs
BMP 8	School Education Programs
BMP 9	Conservation Programs for Commercial, Industrial, and Institutional Accounts
BMP 10	Wholesale Agency Assistance Programs (New)
BMP 11	Conservation Pricing
BMP 12	Conservation Coordinator (Formerly BMP 14)
BMP 13	Water Waste Prohibition
BMP 14	Residential ULFT Replacement Programs (Formerly BMP 16)

Highlights of the Urban MOU

Shown below are several excerpts from the urban MOU that are relevant to the water conservation measures discussed in Chapters 4 and 6.

Recital F It is the intent of this MOU that individual signatory water suppliers (1) develop comprehensive conservation BMP programs using sound economic criteria and (2) consider water conservation on an equal basis with other water management options.

Recital G It is recognized that present urban water use throughout the State varies according to many factors including, but not limited to, climate, types of housing and landscaping, amounts and kinds of commercial, industrial and recreational development, and the extent to which conservation measures have already been implemented. It is further recognized that many of the BMPs identified in Exhibit 1 to this MOU have already been implemented in some areas and that even with broader employment of BMPs, future urban water use will continue to vary from area to area. Therefore, this MOU is not intended to establish uniform per capita water use allotments throughout the urban areas of the State. This MOU is also not intended to limit the amount or types of conservation a water supplier can pursue or to limit a water supplier's more rapid implementation of BMPs.

Section 4.1 (c) Assumptions for use in developing estimates of reliable savings from the implementation of BMPs. Estimates of reliable savings are the water conservation savings which can be achieved with a high degree of confidence in a given service area. The estimate of reliable savings for each BMP depends upon the nature of the BMP and upon the amount of data available to

evaluate potential savings. For some BMPs (e.g., public information) estimates of reliable savings may never be generated. For others, additional data may lead to significant changes in the estimate of reliable savings. It is probable that average savings achieved by water suppliers will exceed the estimates of reliable savings.

Section 4.5 Exemptions. A signatory water supplier will be exempt from the implementation of specific BMPs for as long as the supplier substantiates each reporting period that, based upon then prevailing local conditions, one or more of the following findings applies: (a) A full cost-benefit analysis, performed in accordance with the principles set forth in Exhibit 3, demonstrates that either the program (i) would not be cost-effective overall when total program benefits and costs are considered; OR (ii) would not be cost-effective to the individual water supplier even after the water supplier has made a good faith effort to share costs with other program beneficiaries.

(b) Adequate funds are not and cannot reasonably be made available from sources accessible to the water supplier including funds from other entities. However, this exemption cannot be used if a new, less cost-effective water management option would be implemented instead of the BMP for which the water supplier is seeking this exemption.

(c) Implementation of the BMP is (i) not within the legal authority of the water supplier; and (ii) the water supplier has made a good faith effort to work with other entities that have the legal authority to carry out the BMP; and (iii) the water supplier has made a good faith effort to work with other relevant entities to encourage the removal of institutional barriers to the implementation of BMPs within its service area.

Bulletin 160-98 estimates water savings due to BMP implementation based on the assumptions set forth in Exhibit 1 of the urban MOU, and assumes that California will achieve a level of water conservation equivalent to that expected from full BMP implementation by 2020. The MOU specifies implementation schedules, water use reduction factors, and installation and/or compliance rates that allow quantification of water savings for 7 of the 14 BMPs. The MOU identifies the remaining BMPs as not having quantifiable water savings. The Bulletin's estimated water savings (Appendix 4B) are based on evaluation of the following BMPs in accordance with the Exhibit 1 provisions: residential water use surveys, residential plumbing retrofits, distribution system water audits/leak detection/repairs, metering with commodity rates, programs for commercial/industrial/institutional accounts, and residential ultra-low flush toilet replacement. Water savings for the BMP on large land-

scape water conservation (3 acres or greater) could not be evaluated due to lack of data on existing irrigated landscape acreage.

BMP implementation is estimated to result in a statewide 2020 demand reduction of 1.5 maf statewide. As discussed in Chapter 6, this demand reduction is not the same as creating new water supply. Only conservation actions that reduce irrecoverable losses or reduce depletions actually create new water supply from a statewide perspective. Table 4-4 shows applied water and depletion reductions due to BMP implementation by hydrologic region.

As more water conservation measures are implemented, especially structural changes such as plumbing retrofits, it will become increasingly difficult for urban water agencies and their customers to achieve drought year demand reductions. Demand hardening is discussed in more detail in Chapter 6. The urban MOU acknowledges that demand hardening will be a

TABLE 4-4
**Annual Reductions in Applied Water and
 Depletions Due to BMP Implementation by
 2020 (taf)**

<i>Region</i>	<i>Applied Water</i>	<i>Depletion</i>
North Coast	20	11
San Francisco Bay	176	172
Central Coast	48	30
South Coast	768	500
Sacramento River	91	0
San Joaquin River	111	30
Tulare Lake	125	50
North Lahontan	5	2
South Lahontan	59	21
Colorado River	111	52
Total	1,514	868

consequence of BMP implementation.

Although there are other urban water conservation programs besides those associated with the urban MOU, only the MOU presently addresses quantification of water savings. EPA has started developing water conservation guidelines pursuant to Section 1455 of the 1996 SDWA. USBR has developed guidelines for Reclamation Reform Act water conservation plans and for the more detailed conservation plans required by CVPIA. The USBR conservation plans apply to both urban and agricultural contractors, and are described in more detail in a later section on agricultural water conservation.

Effects of Droughts on Urban Water Production. To illustrate the effects of droughts, Figure 4-4 shows statewide per capita urban water production over time. (Per capita production is the water provided by urban suppliers, divided by population. Urban water

production is not the same as total urban water use; total use includes self-produced supplies, water for recreation and energy production uses, and losses from major conveyance facilities.) After the severe, but brief, 1976-77 drought, statewide urban per capita water production rates returned to pre-drought levels within 3 to 4 years. During the longer 1987-92 drought, urban per capita water production rates declined by about 19 percent on the average statewide. (Most requirements for water-conserving plumbing fixtures did not take effect until after the 1987-92 drought.) The Department's data show increases in per capita water production following the drought, due to removal of mandatory water rationing and other short-term restrictions. When viewed at a statewide level, the data show a strong response to hydrologic conditions.

Urban Water Use Planning Activities

The Department has surveyed retail water agencies and analyzed their water production data for more than 35 years, publishing the data in the Bulletin 166 series, *Urban Water Use in California*. Bulletin 166-4, published in 1994, summarized monthly urban water production data from 1980-90 for nearly 300 retail water purveyors throughout the State. This water use information, updated in the Department's annual surveys, is a primary data source for water use estimates made for Bulletin 160. The Department also conducted a statewide survey of industrial water use by water-using sector in 1994. Industrial water use information is periodically published in the Department's Bulletin 124 series, *Industrial Water Use in California*.

The Urban Water Management Planning Act requires that urban water suppliers with 3,000 or more connections, or that deliver over 3 taf of water per year, prepare urban water management plans and submit them to the Department. The initial set of plans was due in 1985; plans are to be updated every five years. Table 4-5 shows the number of agencies affected by the law and those submitting their 1995 plans as of March 1997. The 1995 plans received were from agencies representing almost 90 percent of all urban water deliveries. These plans have multiple purposes, including demonstrating how local agencies

FIGURE 4-4
**Statewide Average Per Capita
 Urban Water Production Over Time**

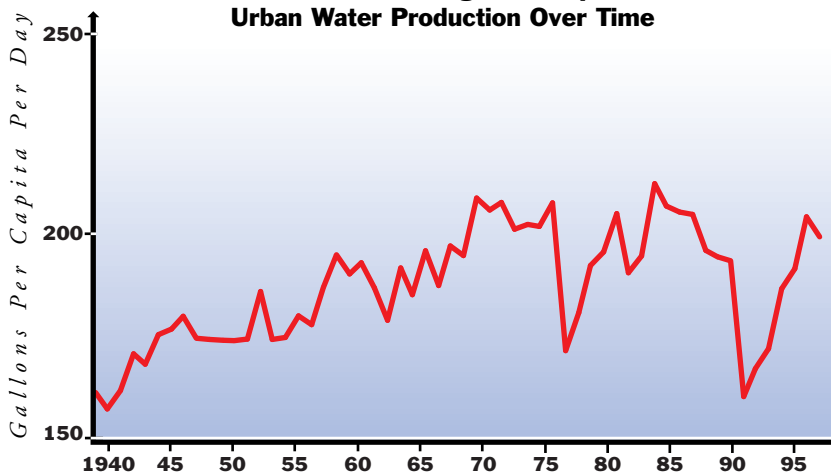


TABLE 4-5
**1995 Urban Water Management Plans by
 Hydrologic Region**

<i>Region</i>	<i>Expected</i>	<i>Filed</i>
North Coast	13	10
San Francisco Bay	60	46
Central Coast	28	17
South Coast	187	152
Sacramento River	35	33
San Joaquin River	29	12
Tulare Lake	22	13
North Lahontan	5	2
South Lahontan	12	11
Colorado River	13	6
Total	404	302

propose to implement water conservation measures and how the agencies plan to meet drought year water supply reliability goals.

The CALFED Bay-Delta program includes water use efficiency—urban, agricultural, and environmental—as one of the common elements required for all proposed Delta alternatives. As described in the water use efficiency technical appendix for the March 1998 draft programmatic EIR/EIS, potential elements of an urban water use efficiency program include:

- Requirements that urban water management plans be implemented more vigorously and that the Department review and certify those plans.
- Revisions to the BMPs to make them more quantifiable.
- Requirements that CUWCC certify BMP implementation.
- Provision of financial and technical assistance to water agencies to encourage program implementation.

CALFED is also examining ways to require that the urban water use efficiency program be implemented vigorously. For example, urban water agencies that choose not to implement the program could be excluded from participation in water transfers requiring approval by a CALFED agency, from use of facilities operated by a CALFED agency, from new supplies made available by a CALFED actions, or from participating in certain loan and grant programs. In addition, CALFED has suggested that SWRCB could be asked to pursue its obligations to investigate waste and unreasonable use more vigorously. Methods to achieve assurances remain under discussion. Depending on the methods chosen, amendments to existing statutes or

execution of new agreements would be needed. Quantification of CALFED's future water use efficiency program is discussed in Chapter 6.

Urban Water Use Forecasting

Urban water use forecasting relates future use to changes in factors influencing water use. Early forecasting methods were relatively simple and relied only on service area population to explain water use, assuming a direct relationship between population growth and applied water demand. These methods can provide acceptable results over the short term, especially during periods of abundant water supply and steady economic growth. However, mid- to long-term forecast accuracy may decrease sharply due to changes in other variables influencing water use. Among these factors are changes in the ratio of single to multifamily dwellings, commercial and industrial growth, income, future water conservation actions, and water pricing. The price of water currently plays a small role in water use; it could become more important if water prices increased substantially. The water price elasticity section in Appendix 4A provides more detail on this subject. New urban water supplies will be relatively expensive, so understanding interactions between price and water use is important for forecasting urban use. As described in the appendix, the Department's forecast used single family residential price elasticities of -0.1 for winter months and -0.2 for summer months.

The Department forecasted change in per capita water use in each hydrologic region to estimate 2020 urban applied water by hydrologic region. Variables included population, income, economic activity, water price, and conservation measures (implementation of urban BMPs and changes to State and federal plumbing fixture standards). The general forecasting procedure was to determine 1995 base per capita water use, estimate the effects of conservation measures and socioeconomic change on future use for 20 major representative water service areas in California, and calculate 2020 base per capita water use by hydrologic region from the results of service area forecasts.

1995 Base Per Capita Water Use. The 1995 base per capita water use includes water supplied by public water systems for municipal and industrial purposes and self-produced (not delivered by a water purveyor) surface water and groundwater. Per capita water use is not the same as the applied water use shown in Bulletin 160 water budgets. Per capita use does not include recreation water use, energy production water use, and

losses from major conveyance facilities (the urban share of the “other” water demand category used in Bulletin 160-93). In most hydrologic regions, 1995 base per capita water use was calculated for each of the Department’s DAUs. In the South Lahontan and Colorado River regions, analyses were done at the PSA level due to the relatively sparse populations in those regions.

The 1995 base per capita water use was computed from normalized water use data to account for variation in annual weather patterns, water supply, and residual effects of the 1987-92 drought. Appendix 4C discusses the relationship between normalized data and actual urban water production data. Actual urban water use during 1995 was less than the Bulletin 160-98 base level in many areas, largely due to wet hydrologic conditions that decreased landscape irrigation requirements. (Likewise, urban water use during a dry year would likely exceed base year use due to higher landscape irrigation water use, assuming no constraints on water supplies). Base per capita 1995 water use was developed from historical water use during recent years with normal water supply and water use patterns. Data for years during and immediately following the drought were removed from consideration due to the effects of water shortages of unprecedented severity and duration, mandatory and voluntary rationing programs, and a multi-year post-drought rebound in per capita water use on water use patterns. The 1995 base was computed from the 1990 per capita use in Bulletin 160-93, adjusted to account for permanent effects of urban BMPs and post-1990 changes to federal and State plumbing fixture standards. The most significant post-1990 change to the plumbing fixture standards was that all toilets for sale or installation in California must use no more than 1.6 gallons per flush, compared to 3.5 gallons or more per flush for older toilets. Plumbing code effects were quantified based on the proportion of total housing stock subject to the new code. ULFT retrofit water savings were estimated based on information on toilet retrofit programs from local water agencies. The final 1995 base value for each DAU was weighted by population to yield 1995 base per capita water use by hydrologic region.

2020 Per Capita Water Use Forecast. Forecasts for the urban water use study were based on three types of input data: actual values of base year water and socioeconomic variables, forecasted values of socioeconomic variables for the year 2020, and savings assumptions for BMPs. Table 4-6 lists the input

TABLE 4-6
Urban Water Use Study Input Variables

<i>Water Use</i>
Water use by sector, base year
Single family
Multifamily
Commercial
Industrial
Landscape
Seasonal water use, base year
<i>Socioeconomic</i>
Population, base year, and forecast year
Total population
Population by dwelling type
Persons per household by dwelling type
Group quarters population
Housing, base year, and forecast year
Number of housing units by dwelling type
Growth rate of housing stock by dwelling type
Employment, base year, and forecast year
Commercial
Industrial
Income, base year, and forecast year
Water price, base year, and forecast year

variables specified for each water service area. Table 4-7 shows data sources for the study.

The urban water use study estimated future change in per capita water use in 20 representative water service areas. (The results in Tables 4-8 and 4-9 display changes from 1990, rather than from the Bulletin’s 1995 base year, to illustrate all effects of water conservation implementation, including the changes in plumbing fixture standards that began in 1992.) The results of the 20 individual model runs were extrapolated to forecast 2020 level per capita water use by hydrologic region (Tables 4-9 and 4-10). The difference between the 1995 and 2020 base levels reflects the influence of water conservation measures, socioeconomic change, and differential population growth on per capita water use in each region.

The forecast results for the representative water service areas were expressed as a percent change in per capita use by 2020, and were averaged (weighted by service area population) to arrive at the percent change in per capita use by hydrologic region. For each region, the 2020 change was applied to the 1995 level per capita water use in each DAU to obtain 2020 per capita water use. The 2020 per capita water use then

TABLE 4-7
Urban Water Use Study Data Sources

<i>Water Use</i>
Survey of Public Water System Statistics, DWR
Urban water management plans
Regional and local water agency reports on water use and conservation
<i>Socioeconomic</i>
Census of Population and Housing, U.S. Department of Commerce
Survey of Current Business, USDC
Statistical Abstract of the United States, USDC
California Statistical Abstract, DOF
California Population Characteristics, Center for Continuing Study of the California Economy
Population Projections by Race and Ethnicity for California and its Counties 1990-2040, DOF
Regional and local planning agencies

TABLE 4-8
**Model Study Results—Per Capita Water Use With Economic
 Growth and Conservation Measures**

<i>Region</i>	<i>Representative Water Service Area</i>	<i>1990 (gpcd)</i>	<i>2020 (gpcd)</i>	<i>Percent Change from 1990</i>	
				<i>Economic Effects</i>	<i>Conservation Effects</i>
North Coast	City of Santa Rosa	156	136	-14	2
San Francisco Bay	EBMUD	196	171	-16	3
	Marin Municipal WD	153	136	-16	5
	City and County of San Francisco	132	115	-16	3
Central Coast	California Water Service Company, Salinas	153	132	-14	0
	City of Santa Barbara	177	156	-15	4
South Coast	City of Los Angeles	180	158	-16	4
	City of San Bernardino	269	243	-11	1
	San Diego County WA	196	176	-14	4
Sacramento River	California Water Service Company, Chico	296	272	-10	2
	City of Sacramento	290	263	-13	3
San Joaquin River	California Water Service Company, Stockton	187	162	-12	-1
	City of Merced	336	299	-10	0
Tulare Lake	California Water Service Company, Visalia	273	235	-11	-3
	City of Fresno	285	262	-10	2
North Lahontan	South Lake Tahoe PUD	179	147	-15	-2
South Lahontan	Indian Wells Valley WD	247	230	-10	3
	Victor Valley County WD	340	322	-8	3
Colorado River	City of Blythe	349	326	-11	4
	City of El Centro	221	197	-13	2

TABLE 4-9
**2020 Change in Per Capita Use by Hydrologic Region—
 Application of Model Results^a**

<i>Region</i>	<i>Economic Effects % Change from 1990</i>	<i>Conservation Effects % Change from 1990</i>
North Coast	2	-14
San Francisco Bay	3	-16
Central Coast	2	-15
South Coast	4	-14
Sacramento River	3	-12
San Joaquin River	-1	-12
Tulare Lake	1	-10
North Lahontan	-2	-15
South Lahontan	3	-9
Colorado River	3	-12
Statewide	3	-15

^a Model results applied to per capita use in each DAU.

TABLE 4-10
**Effects of Conservation on Per Capita Water Use^a by Hydrologic Region
 (gallons per capita per day)**

<i>Region</i>	<i>1995</i>	<i>2020</i>	
		<i>without conservation</i>	<i>with conservation</i>
North Coast	249	236	215
San Francisco Bay	192	188	166
Central Coast	179	188	166
South Coast	208	219	191
Sacramento River	286	286	264
San Joaquin River	310	307	274
Tulare Lake	298	302	268
North Lahontan	411	390	356
South Lahontan	282	294	268
Colorado River	564	626	535
Statewide	229	243	215

^a Includes residential, commercial, industrial, and landscape use supplied by public water systems and self-produced surface and groundwater. Does not include recreational use, energy production use, and losses from major conveyance facilities. These are normalized data.

was multiplied by the population forecast to compute 2020 urban applied water use for each DAU. The DAU-level results were aggregated and combined with minor components of urban use (conveyance losses, recreation water use, and energy production water use) to obtain total applied urban water demands.

This method of computing future water use captures localized effects of differential population growth. The most significant example of variation in growth patterns is the relatively high growth rate in warmer, drier inland areas of California where increased landscape irrigation requirements are reflected in higher per capita use values. Growth in inland areas tends to partially offset reductions in per capita use due to water conservation.

Summary of Urban Water Use

Table 4-11 summarizes Bulletin 160-98 urban applied water use by hydrologic region. Statewide urban use at the 1995 base level is 8.8 maf in average water years and 9.0 maf in drought years. (Drought year demands are slightly higher because less precipitation is available to meet exterior urban water uses, such as landscape watering.) Forecasted 2020 use increases to 12.0 maf in average years and 12.4 maf in drought years. Full implementation of urban BMPs is estimated to result in demand reduction of 1.5 maf in average year water use by 2020. Without implementation of urban BMPs, average year use would have increased to 13.5 maf.

TABLE 4-11
Applied Urban Water Use by Hydrologic Region (taf)

<i>Region</i>	<i>1995</i>		<i>2020</i>	
	<i>Average</i>	<i>Drought</i>	<i>Average</i>	<i>Drought</i>
North Coast	169	177	201	212
San Francisco Bay	1,255	1,358	1,317	1,428
Central Coast	286	294	379	391
South Coast	4,340	4,382	5,519	5,612
Sacramento River	766	830	1,139	1,236
San Joaquin River	574	583	954	970
Tulare Lake	690	690	1,099	1,099
North Lahontan	39	40	50	51
South Lahontan	238	238	619	619
Colorado River	418	418	740	740
Total (rounded)	8,770	9,010	12,020	12,360

As indicated in the Table 4-11, the South Coast and San Francisco Bay Hydrologic Regions together amount to over half of the State's total urban water

use. The table also illustrates that precipitation plays a small role in meeting urban outdoor water needs (landscape water needs) in arid regions such as the Tulare Lake, South Lahontan, and Colorado River regions.



All of the acreage amounts discussed in this chapter are irrigated acres, because estimates of irrigated acreage are needed to calculate agricultural water use. Crop production also occurs (to a much lesser extent) on non-irrigated lands. Dry-farmed grains are an example of crop production on non-irrigated lands.

Agricultural Water Use

The Department's estimates of agricultural water use are derived by multiplying water use requirements for different crop types by their corresponding irrigated acreage, and summing the results to obtain a total for irrigated crops in the State. This section begins by covering crop water use requirements, including demand reduction from water conservation programs. Irrigation efficiency and distribution uniformity are discussed in detail. A description of the process for forecasting irrigated acreage and factors affecting acreage forecasts follows. Forecasted 2020 agricultural water demands are summarized at the end of the section.

Crop Water Use

The water requirement of a crop is directly related to the water lost through evapotranspiration. The amount of water that can be consumed through ET depends in the short term on local weather and in the long term on climatic conditions. Energy from solar radiation is the primary factor that determines the rate of crop ET. Also important are humidity, temperature, wind, stage of crop growth, and the size and aerodynamic roughness of the crop canopy. Irrigation frequency affects ET after planting and during early growth because evaporation increases when the soil

There is a perception that only drip irrigation is an efficient agricultural water use technology. As described in Chapter 5, high efficiencies are possible with a variety of irrigation techniques. Considerations such as soil type, field configuration, and crop type influence the choice of irrigation technique.



surface is wet and is exposed to sunlight. Growing season ET varies significantly among crop types, depending primarily on how long the crop actively grows.

Direct measurement of crop ET requires costly investments in time and sophisticated equipment. There are more than 9 million acres of irrigated crop land in California, encompassing a wide range of climate, soils, and crops. Even where annual ET for two areas is similar, monthly totals may differ. For example, average annual ET for Central Coast interior valleys is similar to that in the Central Valley. Central Valley ET is lower than that in coastal valleys during the winter fog season and higher during the hot summers. Obtaining actual measurements for every combination of environmental variables would be prohibitively difficult and expensive. A more practical approach is to estimate ET using methods based on correlation of measured ET with observed evaporation, temperature, and other climatologic conditions. Such methods can be used to transfer the results of measured ET to other areas with similar climates.

The Department uses the ET/evaporation correlation method to estimate growing season ET. Concurrent with field measurement of ET rates, the Department developed a network of agroclimate stations to determine the relationship between measured ET rates and pan evaporation. Data from agroclimatic studies show that water evaporation from a standard water surface (the Department uses the U.S. Weather Bureau Class A evaporation pan) closely correlates to crop ET. The ET/evaporation method estimates crop water use to within ± 10 percent of measured seasonal ET.

Crop coefficients are applied to pan evaporation data to estimate evapotranspiration rates for specific crops. (Crop coefficients vary by crop, stage of crop growth, planting and harvest dates, and growing season duration.) The resulting data, combined with information on effective rainfall and water use efficiency, form the basis for calculating ETAW and applied water use. Crop applied water use includes the irrigation water required to meet crop ETAW and cultural water requirements.

The amount of water applied to a given field for crop production is influenced by considerations such as crop water requirements, soil characteristics, the ability of an irrigation system to distribute water uniformly on a given field, and irrigation management practices. In addition to ET, other crop water requirements can include water needed to leach soluble salts below the crop root zone, water that must be applied for frost protection or cooling, and water for seed germination. The amount required for these uses depends upon the crop, irrigation water quality, and weather conditions.

Part of a crop's water requirements can be met by rainfall. The amount of rainfall beneficially used for crop production is called effective rainfall. Effective rainfall is stored in the soil and is available to satisfy crop ET or to offset water needed for special cultural practices such as leaching of salts. Irrigation provides the remainder of the crop water requirement. Irrigation efficiency influences the amount of applied water needed, since a portion of each irrigation goes to system leaks and deep percolation of irrigation water below the crop root zone.

The Bulletin's 1995 base applied agricultural water use values were computed from normalized data to account for variation in annual weather patterns and water supply. Normalizing entails applying crop coefficients to long-term average evaporative demand data. Actual applied crop water use during 1995 was less than the Bulletin 160-98 base in many areas due to wet hydrologic conditions that increased effective rainfall, thus decreasing crop ETAW. Likewise, applied water use during a dry year (assuming no constraints on water supplies) would likely exceed the base due to less than average effective rainfall with an attendant

increase in crop ETAW. For most hydrologic regions, 1995 base applied water use was computed for the major crop types found in each of the Department's DAUs. Analyses were done at the planning subarea level in the South Lahontan and Colorado River Regions.

Figure 4-5 shows ranges of 1995 base applied water and ETAW for some common California crops or crop types. ETAW represents a major depletion of water supply, and therefore is an important component of statewide and local water supply planning, groundwater modeling, and water transfer feasibility studies. Except in areas adjacent to the ocean, or areas where the groundwater or surface water is unacceptable for reapplication, irrigation water applied in excess of ET and cultural requirements (e.g., frost protection) is available to downstream users or to users pumping from groundwater.

The purpose of the data presented in Figure 4-5 is to illustrate how great the range of applied water and ETAW can be for a single crop or crop type in California. Climate and soil types are major factors that affect crop water use. Other factors include farming practices, irrigation systems, and water availability. Crop water use is extremely site-specific, and no one value of crop water use can be expected to represent a statewide condition.

Factors Influencing Agricultural Water Use

Irrigation Water Use Efficiency. Distribution uniformity is an important element in on-farm irrigation water use efficiencies. DU measures the variation in the amount of water applied to the soil throughout the irrigated area. Since no irrigation system is capable of applying and distributing water uniformly to all parts of a field, growers often apply enough water to meet crop water requirements of the driest part of the field to achieve optimum crop yields. Achieving a high DU requires excellent system design, maintenance, and management. Irrigation experts maintain that current hardware design and manufacturing technology limit the DU of most systems to 80 percent. As design and manufacturing technology advance and more refined manufacturing processes and hardware are developed, it may be possible to achieve DUs up to 90 percent. Chapter 5 describes the relationship of DU to irrigation efficiencies in more detail.

Seasonal application efficiency is the sum of ETAW and cultural water requirements (such as for leaching salts below the root zone) divided by applied water.

SAE is an appropriate index of water use efficiency for planning purposes, because it is based on the amount of water required to fully satisfy crop water needs while maintaining the favorable salt balance in the root zone required for long-term sustainability of agriculture. It differs from values of irrigation efficiency calculated by growers to compare the amount of water beneficially used to the amount applied, because the amount beneficially used may be less than that needed to fully satisfy crop and cultural water requirements. Efficiency measures used by growers, such as DU and IE, are typically based on the average amount of water infiltrating the quarter of the field receiving the least water. These methods presume that one-half of the low quarter, or 12.5 percent of the field, is under-irrigated to some degree. The result is inadequate leaching and a reduction in crop yield in that part of the field.

Values of SAE cannot be directly compared to IE values commonly cited in literature because they are based on different levels of irrigation effectiveness. Optimal SAE occurs when the driest part of the field receives an amount of water equal to ETAW plus leaching water requirements, resulting in a 100 percent effective irrigation. On the other hand, optimal IE occurs when the amount infiltrated in the low quarter equals ETAW plus leaching requirements, resulting in an 87.5 percent effective irrigation. (Since DU is also calculated based on the low-quarter method, optimal IE is equivalent to DU.) SAE is related to DU and to optimal IE by a linear function so that, for example, a DU of 75 percent implies an optimal SAE of 67 per-

TABLE 4-12
Relationship Among Agricultural Water Use Efficiency Measures

<i>Distribution Uniformity</i>	<i>Irrigation Efficiency^a</i>	<i>Seasonal Application Efficiency^a</i>
90	90	87
85	85	80
80	80	73
75	75	67
70	70	60

^a Optimal values

cent. The relationship among DU and optimal values of IE and SAE is illustrated in Table 4-12. The maximum efficiency values achieved on-farm are generally less than shown due to conveyance losses, evaporation, and uncollected surface runoff.

Relationships between on-farm and regional efficiencies are complex. Often a portion of irrigation water applied to a field runs off the field or percolates into groundwater. Runoff and/or deep percolation from a given field may be considered a water loss to that particular field; nevertheless, this water is not lost to the system unless it goes directly to a nonreusable water source such as saline groundwater or to the ocean. If water quality is good, that water may be reapplied on a field or on other fields several times. Irrigation efficiency formulas developed for on-farm irrigation management cannot necessarily be applied to larger areas or regions. Numerical values of on-farm and regional efficiencies almost always differ. On-farm

Efficient Water Management Practices for Agricultural Water Suppliers in California

List A—Generally Applicable EWMPs

- Prepare and adopt a water management plan
- Designate a water conservation coordinator
- Support the availability of water management services to water users
- Improve communication and cooperation among water suppliers, water users, and other agencies
- Evaluate the need, if any, for changes in institutional policies to which the water supplier is subject
- Evaluate and improve efficiencies of the water supplier's pumps

List B—Conditionally Applicable EWMPs

- Facilitate alternative land use
- Facilitate using available recycled water that otherwise would not be used beneficially, meets all health and safety

criteria, and does not cause harm to crops or soil

- Facilitate financing capital improvements for on-farm irrigation systems
- Facilitate voluntary water transfers that do not unreasonably affect the water user, water supplier, the environment, or third parties
- Line or pipe ditches and canals
- Increase flexibility in water ordering by, and delivery to, water users within operational limits
- Construct and operate water supplier spill and tailwater recovery systems
- Optimize conjunctive use of surface and groundwater
- Automate canal structures

List C—Other EWMPs

- Water measurement and water use reporting
- Pricing or other incentives

efficiencies are usually lower than regional efficiencies due to reapplication of water in a region. A region can reach very high efficiencies as a result of a few reapplications, even if on-farm efficiencies are fairly low. Practices that encourage reapplication, such as tailwater return and spill recovery systems, provide an opportunity to increase regional efficiency. Water reapplication can be the fastest and most economical way to boost regional efficiencies.

Agricultural Water Conservation Programs. The amount of applied water saved depends on the actions of both water suppliers and irrigation water users. Achieving high on-farm water use efficiency is accomplished by optimizing many factors including management (such as irrigation scheduling), irrigation method, crop selection, and supply reliability. On-farm evaluations conducted by the Department and others show that irrigation management is more important than irrigation method in improving water use efficiency. (Chapter 5 describes common irrigation methods.)

Bulletin 160-98 quantifies agricultural water conservation based on assumed statewide implementation of the 1996 agricultural MOU described in Chapter 2. The agricultural MOU provides a mechanism for planning and implementing EWMPs (see sidebar) that benefit water suppliers. The primary objective of EWMPs is for suppliers to better serve farmers in order to facilitate improvements in on-farm practices. As of May 1998, 31 agricultural water agencies serving about 3 million acres of land had signed the MOU. Signatories to the MOU have committed to implement specified EWMPs, based on their evaluation of the benefits of each practice.

EWMPs can lessen runoff and deep percolation of irrigation water, reducing the amount of water farmers must order from an irrigation district or pump from their wells. Because the MOU is orientated to water suppliers, it does not specify water use reduction factors and installation and/or compliance rates for farm irrigation system improvements. Therefore, the Department estimated water savings due to EWMPs based on their potential to remove impediments to optimal on-farm efficiency, expressed as increased SAE. SAE resolves the interrelated effects of EWMPs and improved on-farm management into one variable that quantifies the net result of water conservation efforts by water suppliers and irrigation water users. It is expected that increasing use of EWMPs will yield more information on their water savings potential.

Water savings due to agricultural water conservation were quantified for each DAU on the basis of expected improvements in SAE. It is assumed that by 2020 SAE will reach 73 percent in all regions of California, averaged across crop types, farmland characteristics, and management practices. The DU of irrigation methods limits SAE. The average DU of irrigation systems in California is currently in the 70 to 75 percent range, based on irrigation system evaluations conducted by the Department, resource conservation districts, water districts, and others. By 2020, the average DU is expected to be about 80 percent. An irrigation method with a DU of 80 percent can achieve a maximum SAE of about 73 percent, assuming that irrigation events are properly timed, the soil is well drained, and none of the field is under-irrigated.

The Bulletin 160-98 forecast of conservation savings was calculated by comparing two scenarios of 2020 crop applied water demand under differing levels of SAE. First, crop applied water demand was computed based on the 2020 forecast of irrigated acreage and crop mix, but at existing (1995 base) levels of SAE for each major crop category. Then SAE for each crop category was set to the 2020 forecast value and applied water demand was recomputed. Applied water savings due to conservation were taken as the difference in applied water demand under the two scenarios.

Table 4-13 shows that agricultural water conservation would reduce applied water demands by about 800 taf annually by 2020. Such reductions of applied water generally do not create new water supply; in most areas of California, excess irrigation water becomes available to other users. Even so, a reduction in ap-

TABLE 4-13
2020 Agricultural Water Use Reductions Due to Conservation (taf)

<i>Region</i>	<i>Applied Water</i>	<i>Depletion</i>
North Coast	1	0
San Francisco Bay	1	0
Central Coast	82	0
South Coast	31	10
Sacramento River	203	0
San Joaquin River	148	2
Tulare Lake	45	1
North Lahontan	17	0
South Lahontan	20	10
Colorado River	249	210
Total	797	233

plied water can serve other beneficial purposes such as reducing leaching of plant nutrients, reducing degradation of groundwater quality, and reducing agricultural drainage.

Only practices that lessen evaporation from water surfaces, reduce evapotranspiration, or diminish irrecoverable losses actually reduce depletions. Efficient water management practices have relatively little effect on evaporation and ET. It is the location of water use, rather than the conservation measure employed, that is key to determining whether a reduction in irrigation water application translates into a depletion reduction. Agricultural lands adjacent to the ocean, or where the groundwater or surface water is unacceptable for reapplication, have the greatest potential for reducing depletions through efficient water management practices. In California, such agricultural lands are found in the South Coast Region, the west side of the San Joaquin Valley, and the Colorado River Region.

Other water conservation planning requirements exist in addition to those in the agricultural MOU, most notably those applying to water agencies contracting with USBR. (CALFED's proposed future water use efficiency program is discussed in Chapter 6.) The Reclamation Reform Act of 1982 directed DOI to establish a water conservation planning program. In 1992, CVPIA established additional water conservation requirements for federal contractors receiving CVP supplies. USBR published criteria for CVPIA conservation plans and is reviewing the plans which contractors are required to submit. As of March 1998, more than 70 federal water contractors had submitted plans pursuant to CVPIA criteria. Discussions are underway with the agricultural council established by the 1996 MOU regarding developing a way for CVPIA plans to be accepted as plans complying with the agricultural MOU. CVPIA further requires that new, renewed, or amended CVP water service or repayment contracts mandate that surface water delivery systems have water measurement devices or comparable methods of measuring water use.

Agricultural Water Pricing. The relationship of agricultural water pricing to water use and the role of pricing in achieving water conservation have been subjects of discussion in recent years. For water supplied by public agencies, the elected board members of those agencies ultimately have the responsibility for balancing desires to achieve demand reduction through water pricing with desires to provide affordable water rates

to growers. For self-supplied agricultural water users, good business practices dictate maximizing water use efficiency, in terms of crop yield per unit of water applied. Agricultural water prices in California vary widely and are affected by factors such as geographic location and source of water supply. Appendix 4A provides background information on agricultural water pricing. As described in the price elasticity information in the appendix, demand for irrigation water is generally price inelastic over the price ranges evaluated. There is no other commodity that can be substituted for the water required to grow crops. Water costs are typically a relatively small percentage of the total cost of producing most crops.

Crop markets, not water prices, generally dominate the economics of crop production. Bulletin 160-98 considers markets and other economic effects in the modeling performed to forecast future irrigated acreage, as described later in this chapter. When fully implemented, CVPIA tiered pricing requirements may provide new data on water price/water use relationships for CVP contractors, as described in the appendix.

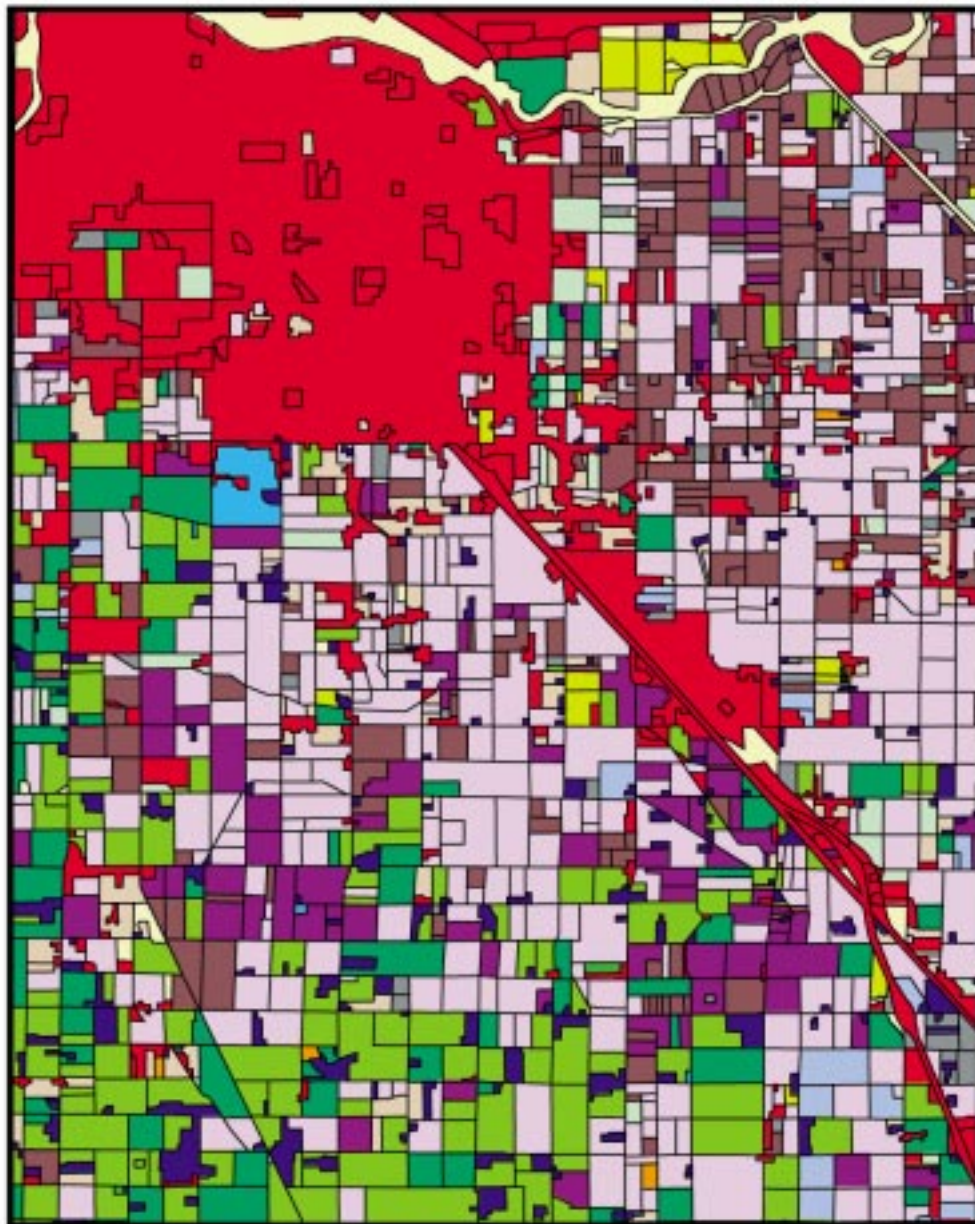
Agricultural Acreage Forecasting

This section describes how 1995 base year irrigated acreage is established, and how that information is used to forecast 2020 irrigated acreage.

Quantifying Present Irrigated Acreage. Forecasts of future agricultural acreage start with land use data that characterize existing crop acreage. The Department has performed land use surveys since the 1950s to quantify acreage of irrigated land and corresponding crop types, and currently maps irrigated acreage in six to seven counties per year. The base data for land use surveys is obtained from aerial photography or satellite imagery, which is superimposed on a cartographic base. Site visits are used to identify or verify crop types growing in the fields. From this information, maps showing locations and acreage of crop types are developed. Figure 4-6 is an example of a typical land use survey map, showing crop types in the Ceres 7.5 minute USGS quadrangle from the Department's 1996 Stanislaus County survey.

The Department's land use surveys focus on quantifying irrigated agricultural acreage. Although fields of dry-farmed crops are mapped in the land use surveys, their acreage is not tabulated for calculating water use. In certain areas of the State, climate and market conditions are favorable for producing multiple crops per year on the same field (for example, winter veg-

FIGURE 4-6
Typical Land Use Survey Map



California's Nursery Industry

When people think of irrigated agriculture, crops that often come to mind are commodities such as hay, grains, rice, row crops, and cotton. However, nursery products (flowers, plants, turf-grass) rank as the State's fourth largest farm product in gross value, behind milk/cream, grapes, and cattle, and ahead of cotton, almonds, and hay, according to 1996 California Department of Food and Agriculture statistics. The prominence of the nursery industry reflects the extent of urbanization in California, as well as favorable climatic conditions.

California nursery products had a \$1.6 billion farmgate value (wholesale value at the farm) in 1996. San Diego is the leading California county in nursery product valuation, followed by Santa Barbara, San Mateo, and Los Angeles Counties. California wholesale production represents about

26 percent of national nursery product sales.

An important difference between the nursery industry and other agricultural sectors is the extent to which the industry's revenues are tied to urban, as well as to agricultural, water supplies. Bulletin 160 treats nursery water use as an agricultural use. Many of the industry's products, however, are destined for urban and commercial locations where urban water supply availability influences landscaping choices and the market for nursery products.

About 25,000 acres are devoted to nursery products in California. Much of the acreage is in proximity to urbanized, coastal regions of the State near markets and major transportation routes.

etables followed by a summer cotton crop). In these cases, annual irrigated acreage is counted as the sum of the acreage of the individual crop types. In the years between county land use surveys, the Department estimates crop types and acreage using data collected from county agricultural commissioners, local water agencies, University of California Cooperative Extension Programs, and the California Department of Food and Agriculture.

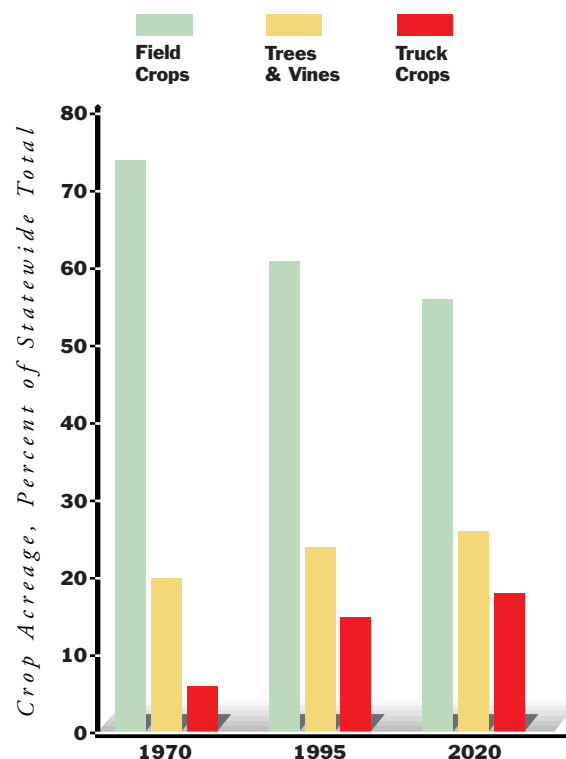
The starting point for determining Bulletin 160-98 1995 base acreage was normalized 1990 irrigated acreage from Bulletin 160-93. Changes in crop acreage between 1990 and 1995 were evaluated to determine if they were due to short-term causes (e.g., drought or abnormal spring rainfall), or if there was an actual change in cropping patterns. Base year acreage was normalized to represent the acreage that would most likely be expected in the absence of weather and market related abnormalities. (More detail on the concept of normalizing base year data is presented in

Chapter 3.) Figure 4-7 illustrates some general trends in California cropping patterns over time.

Crop acreage by region for the normalized 1995 base is presented in Table 4-14. The 1995 base irrigated land acreage is about 9.1 million acres, which, when multiple cropped areas are tabulated, becomes a base irrigated cropped acreage of about 9.5 million acres.

Forecasting Future Irrigated Acreage. The

FIGURE 4-7
General Trends in
Cropping Patterns Over Time



The Central Valley produces most of California's tomato crop. Much of the crop is used for processed tomato products, such as canned tomatoes and tomato sauces. Acreage devoted to truck crops like tomatoes is expected to increase in the future.

TABLE 4-14
California Crop and Irrigated Acreage by Hydrologic Region, 1995 level
(thousands of acres)

<i>Irrigated Crop</i>	<i>NC</i>	<i>SF</i>	<i>CC</i>	<i>SC</i>	<i>SR</i>	<i>SJ</i>	<i>TL</i>	<i>NL</i>	<i>SL</i>	<i>CR</i>	<i>Total</i>
Grain	72	2	26	11	270	180	260	7	2	70	900
Rice	0	0	0	0	494	22	0	1	0	0	517
Cotton	0	0	0	0	9	185	1,026	0	0	24	1,244
Sugar beets	6	0	3	0	54	47	30	0	0	38	178
Corn	1	1	3	4	92	212	116	0	0	9	438
Other field	3	1	16	4	155	120	97	0	1	70	467
Alfalfa	53	0	21	10	149	231	296	44	34	256	1,094
Pasture	122	5	18	20	352	199	49	107	18	43	933
Tomatoes	0	0	10	7	138	82	111	0	0	9	357
Other truck	23	11	382	87	56	130	194	2	3	172	1,060
Almond/pistachios	0	0	0	0	106	251	177	0	0	0	534
Other deciduous	7	6	18	3	219	154	191	0	3	1	602
Subtropical	0	0	19	161	28	8	202	0	0	37	455
Grapes	36	39	56	6	17	184	378	0	0	20	736
Total Crop Area	323	65	572	313	2,139	2,005	3,127	161	61	749	9,515
Multiple Crop	0	0	142	30	52	56	63	0	0	104	447
Irrigated Land Area	323	65	430	283	2,087	1,949	3,064	161	61	645	9,068

Water Use Impacts from Urbanization of Agricultural Lands—A San Joaquin Valley Example

The Department projects a decline in California's irrigated acreage by 2020, due in part to urbanization of agricultural lands. Much of this urbanization will occur in the South Coast Region and in the San Joaquin Valley. Potential changes in water use resulting from land use conversion are often of concern to local agencies responsible for land use planning or for providing water supplies. Changes in water use must be evaluated on a site-specific basis, as the following example for the San Joaquin Valley illustrates.

Changes in water use depend on the kinds of crops grown and the density and type of urban development in an area. In the case of single-family dwellings, applied water use varies with housing density. Numerous studies have shown that dwellings on larger lots use more water per dwelling unit due to the larger landscaped areas. However, higher density developments have the greater applied water use per acre of land. A recent Department study of the Fresno area showed that applied water use of single-family dwellings and agricultural crops were similar at low housing densities (four or five units per acre). However, higher density single-family dwellings (six units or more per acre) that have become common in today's new home construction market tended to have greater applied water requirements than some crops.

Growth in the Fresno area has caused expansion of urban development onto adjoining agricultural lands. Figure 4-8 is a plot of Department land use data illustrating the long-term expansion of urban development onto agricultural lands in the area. Department data show that average urban applied water use in the Fresno area (urban water use includes residential, commercial, and industrial purposes) is equivalent to about 3.2 af/acre. Typical agricultural applied water use for crops grown in the area is shown below. Actual agricultural applied water use for an individual crop will vary with field-specific conditions such as soil type and irrigation method.

<i>Type of Use</i>	<i>Applied Water Use (af/acre)</i>
Urban	3.2
Agricultural	
Barley	1.3
Grapes	2.9
Cotton	3.2
Deciduous orchard	3.5
Pasture (improved)	4.5
Alfalfa	4.7

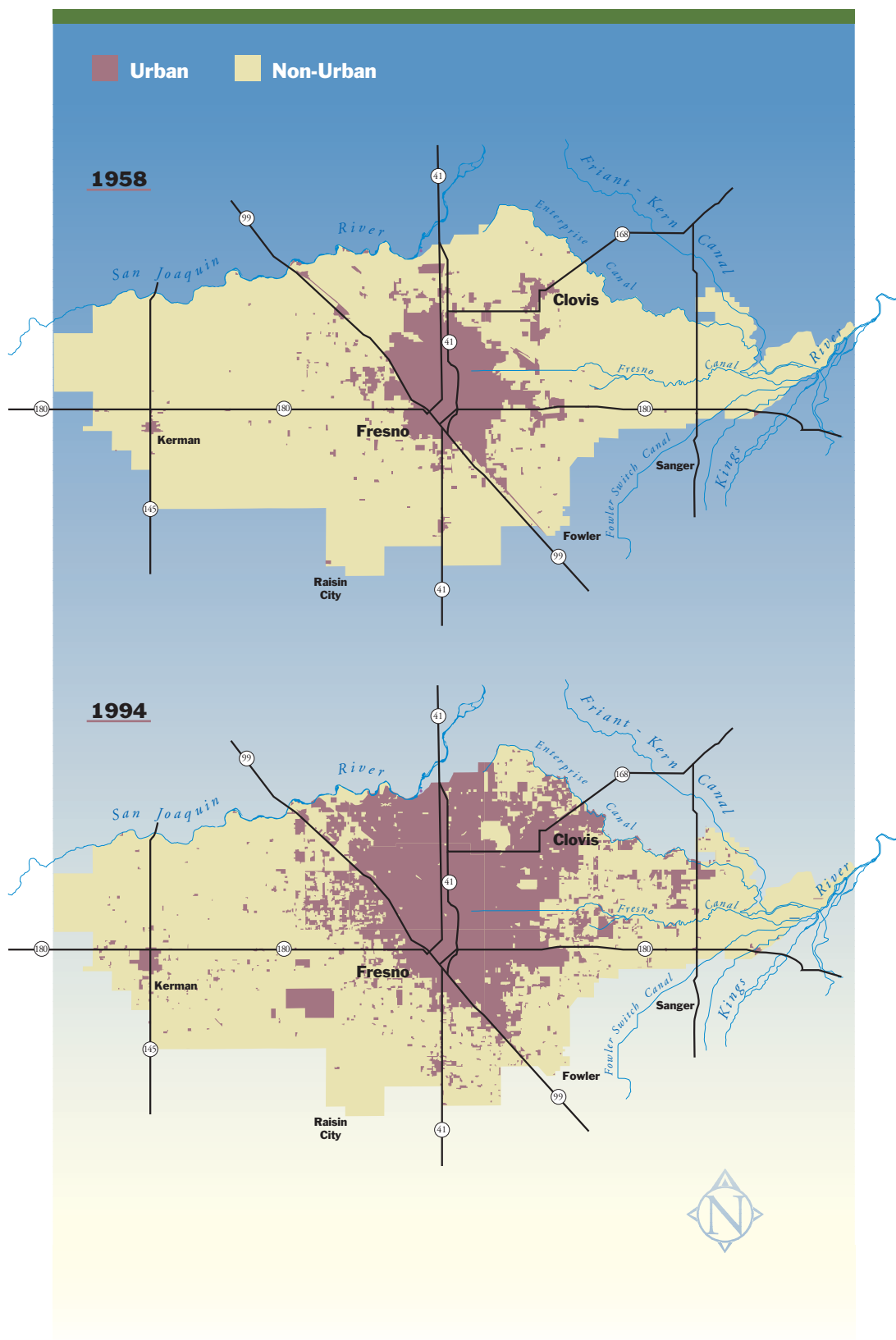
Department's 2020 irrigated acreage forecast was derived from staff research, a crop market outlook study, and results from the Central Valley Production Model. As with any forecast of future conditions, there are uncertainties associated with each of these approaches. The Department's integration of the results from three independent approaches is intended to represent a best estimate of future acreage, absent major changes from present conditions. It is important to emphasize that many factors affecting future cropped acreage are based on national (federal Farm Bill programs) or international (world export markets) circumstances. California agricultural products compete with products from other regions in the global economy and are affected by trade policies and market conditions that reach far beyond the State's boundaries.

The Federal Agriculture Improvement and Reform Act of 1996, for example, affects agricultural markets nationwide, by changing federal price supports for specified agricultural commodities. Under the terms of that act, federal payments to growers will be reduced by 2002, and prior farm bill provisions that required growers to reduce planted acreages of regulated com-

modities are no longer in force. (Commodities with significant federal price support include wheat, feed grains, rice, cotton, dairy products, sugar, and peanuts.) The overall impact of the act to California may be less than its impact to states whose agriculture is less diversified and who are less active in export markets. In 1994, for example, federal farm bill production payments to California growers represented about 1 percent of California's agricultural revenue. The potential impacts of FAIRA to California's agricultural market are considered in Bulletin 160-98 by the crop market outlook study.

Intrastate factors considered in making acreage forecasts included urban encroachment onto agricultural land and land retirement due to drainage problems (discussed in more detail in the following section). Urbanization on lands presently used for irrigated agriculture is a significant consideration in the South Coast Region and in the San Joaquin Valley, based on projected patterns of population growth. (See sidebar on water use impacts of land conversion.) DOF 2020 population forecasts, along with information gathered from local agency land use plans, were used

FIGURE 4-8
Changes in Land Use Over Time, DAU 233



to identify irrigated lands most likely to be affected by urbanization. Local water agencies and county farm advisors were interviewed to assess their perspective on land use changes affecting agricultural acreage. For example, urbanization may eliminate irrigated acreage in one area, but shift agricultural development onto lands presently used as non-irrigated pasture. Soil types and landforms are important constraints in agricultural land development. If urbanization occurs on prime Central Valley farmland, some agricultural production may be able to shift to poorer quality soils on hilly lands adjoining the valley floor. A consequent shift in crop types and irrigation practices would likely result—for example, from furrow-irrigated row crops to vineyards on drip irrigation.

The Department's crop market outlook, a form of Delphi analysis, was developed using information and expert opinions gathered from interviews with more than 130 University of California farm advisors, agricultural bankers, commodity marketing specialists, managers of cooperatives, and others. Three basic factors guided the CMO: current and future demand for food and fiber by the world's consumers; the share California could produce to meet this worldwide demand; and technical factors, such as crop yields, pasture carrying capacities, and livestock feed conversion ratios that affect demand for agricultural products. (Milk and dairy products are California's largest agricultural product, in terms of gross value. The demand for these products is reflected in the markets for alfalfa, grains, and other fodder used by dairies.) The CMO forecasts a statewide crop mix and estimates corresponding irrigated acreage. The major findings of the CMO for year 2020 were that grain and field crop acreage would decrease, while acreage of truck crops and permanent crops would increase.

The Central Valley Production Model is a mathematical programming model that simulates farming decisions by growers. Inputs include detailed information about production practices and costs as well as water availability and cost by source. The model also uses information on the relationship between production levels of individual crops and crop market prices. The model's geographic coverage is limited to the Central Valley, which represents about 80 percent of the State's irrigated agricultural acreage. The CVPM results also indicated future crop shifting, from grains and field crops to vegetables, trees, and vines. The CVPM forecast showed a small reduction in crop acreage from 1995 to 2020.

Other Factors Affecting Forecasted Irrigated Acreage. The process of estimating future irrigated acreage considered statewide factors such as crop markets and urban expansion onto agricultural lands. The Department considered an additional region-specific factor, the long-standing agricultural drainage management issues on the west side of the San Joaquin Valley. Drainage management issues in this area have a dual focus—salt management to permit continued agricultural production on lands requiring drainage systems, and trace minerals management (principally selenium) to limit adverse water quality and environmental impacts.

The need for drainage systems to permit farming in some westside areas was recognized concurrently with the development of irrigated agriculture in the region. USBR's San Luis Drain, for example, was originally planned to convey drainage water out of the valley to the Delta. The drain was instead terminated at Kesterson Reservoir, where waterfowl mortalities led to discovery of elevated selenium levels in the early 1980s. The drain was subsequently closed. (A discussion of trial reopening of part of the drain for the Grasslands Bypass Channel Project is provided in Chapter 8.) Post-Kesterson studies of valley drainage problems have sought to quantify factors such as extent of areas with shallow depths to groundwater, tributary areas in Coast Range sediments from which trace minerals are derived, and water quality characteristics of drain water and shallow groundwater.

The 1990 report of the interagency San Joaquin Valley Drainage Program projected that as much as 460,000 acres of irrigated land would be taken out of production by the year 2020 if the report's recommendations were not implemented. The report recommended retirement of 75,000 acres of land having the worst drainage problems by 2040. The Bulletin 160-98 year 2020 acreage forecast follows the same procedure used in Bulletin 160-93 and assumes that the 75,000 acres would be retired at an average rate of 1,500 acres per year. Thus, 45,000 acres of land would be retired between 1990 and 2020. USBR's 1997 request for proposals for the CVPIA land retirement program (described in Chapter 6) elicited offers to sell 31,000 acres of drainage-impaired lands, suggesting that the assumed 45,000 acres of land retirement could occur by 2020.

Data from the Department's monitoring program for groundwater levels in the San Joaquin Valley are shown in Figure 4-9. Agricultural acreage with a water

FIGURE 4-9
Areas of Shallow Groundwater in the San Joaquin Valley



Agroforestry Research

Agroforestry is being tested for managing drainage impaired lands. Agroforestry systems integrate trees and shrubs into cropping activities to produce marketable products and/or provide resource conservation. Agroforestry principles could be applied to on-farm water management, where increasingly saline water would be applied to successively more salt-tolerant plants to reduce drainage volumes. For example, drainage water from salt-sensitive crops could be used to irrigate a salt-tolerant crop like cotton. Drainage water from the cotton would then be used to irrigate salt-tolerant trees, such as

eucalyptus. Drainage water from the trees would be reused again to irrigate highly salt-tolerant plants such as saltgrass. Finally, the drainage water would be discharged into a solar evaporator. This is an experimental program. To be commercially successful, markets would need to be found for the eucalyptus trees and other biomass produced. In 1985 a cooperative effort among several growers and agencies began at a 27-acre site near Mendota. A second research project of 622 acres was established at Red Rock Ranch in Fresno County in 1993, and a third research project was started by Tulare Lake Basin Drainage District.

table within 10 feet of the surface increased from 1,061,000 acres in 1991 to 1,262,000 acres in 1997. Agricultural lands with a water table within 5 feet of the surface increased from 311,000 acres in 1991 to 743,000 acres in 1997. Increases in the extent of shallow groundwater coincide with the end of drought conditions and above-average rainfall. (The Department's monitoring program is limited to measurement of groundwater levels. There has been no region-wide monitoring of selenium and other constituents in shallow groundwater since the 1987 work performed for the 1990 report.)

To implement recommendations of the 1990 report, four State agencies (DWR, SWRCB, DFG, and

DFA) and four federal agencies (USBR, USFWS, USGS, and Natural Resource Conservation Service) signed a 1991 MOU to participate in a cooperative interagency program. The program was to address the management plan's eight major recommendations: source control, drainage reuse, evaporation ponds, land retirement, groundwater management, limiting discharge to the San Joaquin River, and institutional change. (The plan's recommendations did not address disposal of drain water outside of the Central Valley.) Significant progress has been made on some recommendations. Some examples of drainage management activities are described in Chapters 7-9.

In 1997, the interagency drainage program drafted

Factors that influence the conversion of irrigated lands to urban use include the lands' proximity to existing urban areas and transportation corridors, and local agency land use planning and zoning policies.



an activity plan to update the report's recommendations with new information. The activity plan is scheduled for completion in 1999. Source control objectives of the 1990 report have been achieved or exceeded over large areas. In the first year of Grasslands Bypass Channel Project implementation (described in Chapter 8), irrigation and drainage modifications by Grasslands area farmers reduced selenium discharges to the San Joaquin River. Tiered water pricing has been implemented in the drainage problem area of the Grasslands subarea. Three agroforestry drainage reuse research projects have been implemented (see sidebar).

One factor not included in Bulletin 160-98 irrigated acreage forecasts is the potential large-scale conversion of agricultural land to wildlife habitat for reasons other than the westside drainage problems described above. The CALFED program represents the largest pending example of potential conversion of irrigated agricultural lands to habitat, as described in CALFED's March 1998 draft programmatic EIR/EIS and supporting documents. CALFED's potential land conversion amounts have not been included in the Bulletin 160-98 irrigated acreage forecast because they are preliminary at this time (a site-specific environmental

document with an implementation schedule for land conversion has not yet been prepared), and because CALFED's preliminary numbers are so large relative to the Bulletin's market-based forecast of irrigated acreage that they would negate the results of the forecast. Overall, CALFED program activities as presently planned could convert up to 290,000 irrigated acres to habitat and other uses, an amount almost as great as the 325,000 acre reduction in irrigated acreage forecast in the Bulletin. Water use implications of large-scale land conversions are not included in the Bulletin 160-98 forecast. Impacts of such land conversions are expected to be addressed in the next water plan update, when CALFED's program may be better defined.

The difficulty in estimating impacts from large-scale land conversion programs stems from the domino effect that changes in acreage in one location have on acreage and crop types in other areas, and how crop markets determine which crop shifts are feasible. For example, CALFED's preliminary reports suggest that up to 190,000 irrigated acres in the Delta could be converted to other land uses. This amount represents about 40 percent of Delta irrigated acreage, where principal crops are corn, alfalfa, tomatoes, grain, orchard

Alfalfa and Market Conditions

The market for California alfalfa is closely tied to the State's dairy industry. California is the nation's leading dairy state. According to DFA's 1996 statistics, milk/cream production amounted to \$3.7 billion, making it the State's top-valued agricultural commodity. California, with about 1.3 million dairy cows and over 2,300 dairy farms, accounted for almost 17 percent of the nation's dairy production in 1996. Leading dairy counties are Tulare, San Bernardino, Merced, Stanislaus, and Riverside.

Alfalfa supports the dairy and livestock industries (including the recreational horse industry) and also provides about one-third of the nation's honey production. In-state alfalfa production does not meet all of the demand within California. Alfalfa is trucked from the intermountain states to Central California dairies. Although some alfalfa is exported from California (mostly to Japan), imports into California have exceeded exports by 1 to 8 percent over the past several years.

California milk/cream production has increased more than 50 percent in the past 12 years. About half of this increase is due to increases in milk yield per cow and the remainder is due to increased numbers of cows. This has created a continuing demand for alfalfa. Most dairy rations in California contain some component of alfalfa.

Relatively little raw milk flows into or out of the State. California's dairy industry is based on in-state production and processing capacity. The demand for milk products is greatest in the State's major population centers — the San Francisco Bay Area and urbanized Southern California. Dairy production has been concentrated in the San Joaquin Valley and in the Inland Empire region of Southern California, within convenient distances of major markets. Increasing urbanization of formerly agricultural lands in Southern California is shifting more dairy production to the southern San Joaquin Valley. To supply feed to these dairies, the San Joaquin Valley has become the largest production area for alfalfa in the State, producing nearly half of California's alfalfa.

According to DFA, California's Grade A milk production can be broken down into the following categories:

Cheese	36%
Butter & nonfat dry milk	29%
Fluid milk products	24%
Frozen dairy products	6%
Soft products	5%

TABLE 4-15
California Crop and Irrigated Acreage by Hydrologic Region, 2020 Level
 (thousands of acres)

<i>Irrigated Crop</i>	<i>NC</i>	<i>SF</i>	<i>CC</i>	<i>SC</i>	<i>SR</i>	<i>SJ</i>	<i>TL</i>	<i>NL</i>	<i>SL</i>	<i>CR</i>	<i>Total</i>
Grain	66	1	21	5	249	152	201	8	0	97	800
Rice	0	0	0	0	484	15	0	1	0	0	500
Cotton	0	0	0	0	15	171	888	0	0	46	1,120
Sugar beets	6	0	2	0	52	18	13	0	0	29	120
Corn	2	0	3	2	90	188	101	1	0	3	390
Other field	3	1	14	1	154	139	110	0	0	33	455
Alfalfa	62	0	20	6	147	181	238	50	24	217	945
Pasture	123	5	16	6	316	165	26	103	18	32	810
Tomatoes	0	0	8	4	141	93	130	0	0	14	390
Other truck	28	11	373	43	79	197	300	2	1	231	1,265
Almond/pistachios	0	0	0	0	127	270	198	0	0	0	595
Other Deciduous	7	6	20	3	234	153	199	0	2	1	625
Subtropical	0	0	18	117	33	10	215	0	0	32	425
Grapes	38	41	75	3	29	183	366	0	0	15	750
Total Crop Area	335	65	570	190	2,150	1,935	2,985	165	45	750	9,190
Multiple Crop	0	0	150	10	70	80	100	0	0	145	555
Irrigated Land Area	335	65	420	180	2,080	1,855	2,885	165	45	605	8,635



The proximity of California agriculture to densely populated urban markets encourages the production of specialty crops. Pumpkin patches and Christmas tree lots are examples of specialized urban niche markets.

crops, and truck crops (e.g., asparagus). Some land conversion in the Delta might result in production on new agricultural lands—most likely, rolling hills on the edge of the valley floor which are suitable for only limited crop types (orchards and vineyards). Some of the land conversion might result in increased demand in other areas for the affected crops, such as increased demand for asparagus from the Imperial and Salinas Valleys.

Results of 2020 Acreage Forecast. Table 4-15 shows the 2020 irrigated acreage forecast. The total irrigated crop acreage is forecasted to decline by 325,000 acres from 1995 to 2020, primarily in the San Joaquin Valley and South Coast areas. Reductions in crop acreage are due to urban encroachment, drainage problems in the westside San Joaquin Valley, and a more competitive economic market for California ag-

ricultural products. Pasture and field crops are forecasted to decline by about 631,000 acres. Truck crops and permanent crops are forecasted to increase by about 238,000 and 68,000 acres, respectively. Acreage with multiple cropping is forecasted to increase by 108,000 acres, reflecting the expected increased production of truck crops. These statewide findings are used in developing the forecasted agricultural water demands.

Summary of Agricultural Water Use

Crop water use information and irrigated acreage data are combined to generate the 2020 agricultural water use by hydrologic region shown in Table 4-16. As previously noted, the 2020 forecasted values take into account EWMP implementation, which results in a 2020 applied water reduction of about 800 taf.

TABLE 4-16
Applied Agricultural Water Use by Hydrologic Region (taf)

<i>Region</i>	<i>1995</i>		<i>2020</i>	
	<i>Average</i>	<i>Drought</i>	<i>Average</i>	<i>Drought</i>
North Coast	894	973	927	1,011
San Francisco Bay	98	108	98	108
Central Coast	1,192	1,279	1,127	1,223
South Coast	784	820	462	484
Sacramento River	8,065	9,054	7,939	8,822
San Joaquin River	7,027	7,244	6,450	6,719
Tulare Lake	10,736	10,026	10,123	9,532
North Lahontan	530	584	536	594
South Lahontan	332	332	257	257
Colorado River	4,118	4,118	3,583	3,583
Total (rounded)	33,780	34,540	31,500	32,330

Environmental Water Use

Bulletin 160-98 defines environmental water as the sum of:

- Dedicated flows in State and federal wild and scenic rivers
- Instream flow requirements established by water right permits, DFG agreements, court actions, or other administrative documents
- Bay-Delta outflows required by SWRCB
- Applied water demands of managed freshwater wildlife areas

This definition recognizes that certain quantities of water have been set aside or otherwise managed for environmental purposes, and that these quantities cannot be put to use for other purposes in the locations where the water has been reserved or otherwise managed. This definition also recognizes that these uses of environmental water can be quantified. Unlike urban and agricultural water use, much of this environmental water use is brought about by legislative or regulatory processes. Certainly the environment uses more water than is encompassed in this definition—the rainfall that sustains the forests of the Sierra Nevada and the North Coast, the winter runoff that supports flora and fauna in numerous small streams, the shallow groundwater that supports riparian vegetation in some ephemeral streams—but the Bulletin’s definition captures uses of water that are managed (in one fashion or another) and quantifiable. As described earlier, average annual statewide precipitation over California’s land surface amounts to about 200 maf. About 65 percent of this precipitation is consumed through evaporation and transpiration by the State’s forests, grasslands, and other vegetation. The remaining 35 percent comprises the State’s average annual runoff of about 71 maf. The environmental water demands discussed in this section are demands that would be met through a designated portion of that average annual runoff.

The following discussion covers factors affecting the four categories of environmental water use. As with urban and agricultural water use, options for meeting future environmental water needs—such as federal acquisition and transfer of water to meet CVPIA AFRP goals—are covered in Chapter 6 and in the regional water management chapters. The environmental water use categories below are discussed in order of size—from greatest (wild and scenic rivers) to smallest (wildlife refuges). Environmental water use is shown on an applied water basis.

Flows in Wild and Scenic Rivers

Flows in wild and scenic rivers constitute the largest environmental water use in the State. Figure 4-10 is a map of California’s State and federal wild and scenic rivers.

The 1968 National Wild and Scenic Rivers Act, codified to preserve the free-flowing characteristics of rivers having outstanding natural resources values, prohibited federal agencies from constructing, authorizing, or funding the construction of water resources projects having a direct or adverse effect on the values for which the river was designated. (This restriction also applies to rivers designated for potential addition to the national wild and scenic rivers system.) There are two methods for having a river segment added to the federal system—congressional legislation, or a state’s petition to the Secretary of the Interior for federal designation of a river already protected under state statutes. No new federal designations have been made since publication of Bulletin 160-93.

A number of river systems within lands managed by federal agencies are being studied as candidates. For example, U.S. Forest Service draft environmental documentation in 1994 and 1996 recommended designation of 5 streams (129 river miles) in Tahoe National Forest and 160 river miles in Stanislaus National Forest. These waterways drain to the Central Valley where their flows are used for other purposes, and wild and scenic designation would not affect the existing downstream uses.

The California Wild and Scenic Rivers Act of 1972 prohibited construction of any dam, reservoir, diversion, or other water impoundment on a designated river. As shown on Figure 4-10, some rivers are included in both federal and State systems. No new State designations have been made since Bulletin 160-93, although the Mill and Deer Creeks Protection Act of 1995 (Section 5093.70 of the Public Resources Code) gave portions of these streams special status similar to wild and scenic designation, by restricting construction of dams, reservoirs, diversions or other water impoundments.

Tables 4-17 and 4-18 show the wild and scenic river flows used in Bulletin 160-98 water budgets by waterway and by hydrologic region. The flows shown are based on the rivers’ unimpaired flow. (The unimpaired flow in a river is the flow measured or calculated at some specific location that would be unaffected by stream diversions, storage, imports or exports, and return flows.) For the average year condition, the

FIGURE 4-10
California Wild and Scenic Rivers

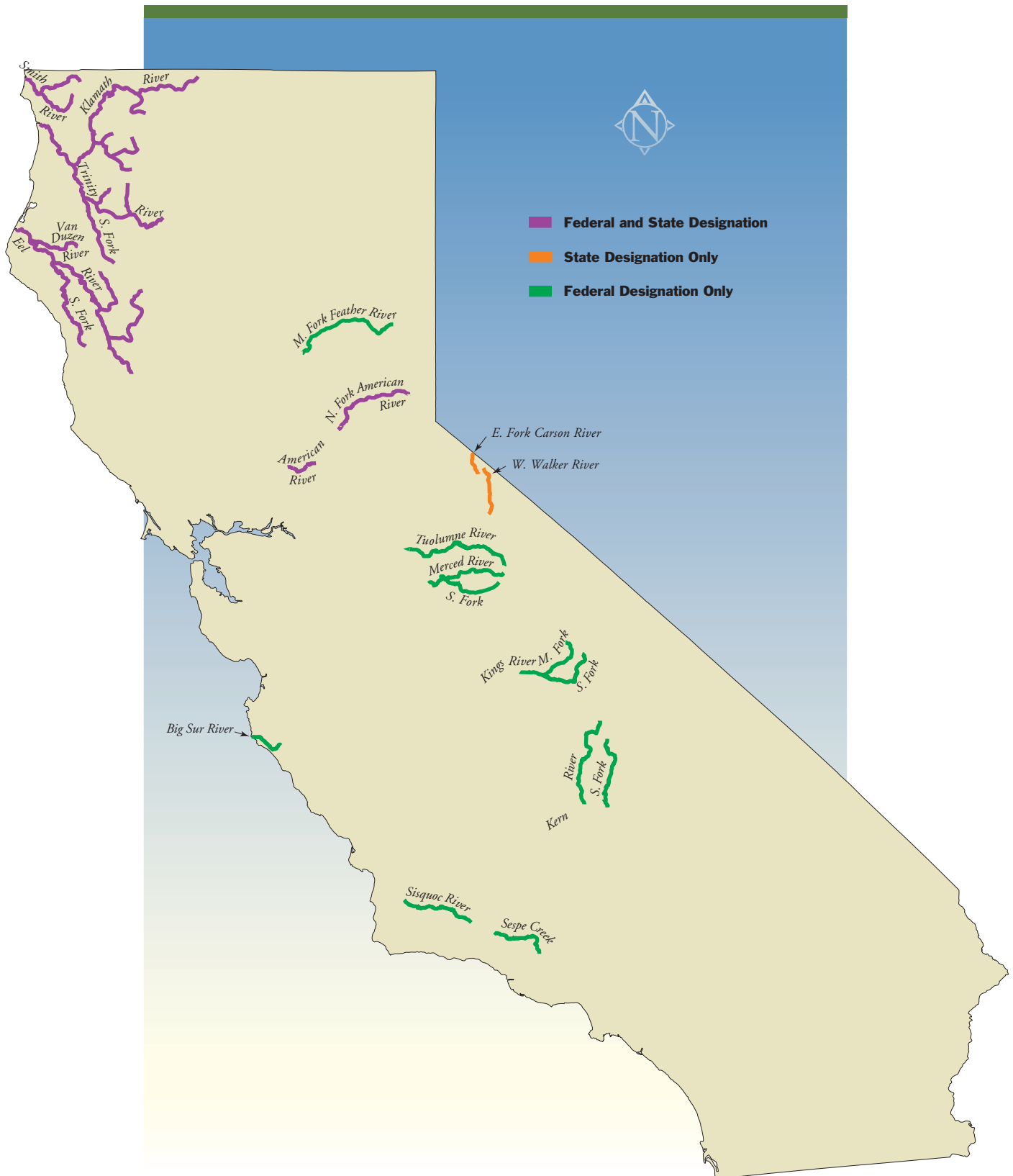


TABLE 4-17
Wild and Scenic River Flows by Waterway (taf)

<i>Waterway</i>	<i>1995</i>		<i>2020</i>	
	<i>Average</i>	<i>Drought</i>	<i>Average</i>	<i>Drought</i>
Klamath	9,070	3,980	9,070	3,980
Smith	2,920	1,720	2,920	1,720
Eel	5,810	2,200	5,810	2,200
Big Sur	83	22	83	22
Sisquoc	15	6	15	6
Sespe Creek	69	51	69	51
Middle Fork Feather	1,129	497	1,129	497
North Fork American	584	239	584	239
Lower American	20	0	20	0
Tuolumne	1,192	572	1,192	572
Merced	782	367	782	367
Kings	896	448	896	448
North Fork Kern	628	275	628	275
South Fork Kern	90	28	90	28
East Fork Carson	71	34	71	34
West Walker	200	120	200	120
Total (rounded)	23,560	10,560	23,560	10,560

TABLE 4-18
Wild and Scenic River Flows by Hydrologic Region (taf)

<i>Region</i>	<i>1995</i>		<i>2020</i>	
	<i>Average</i>	<i>Drought</i>	<i>Average</i>	<i>Drought</i>
North Coast	17,800	7,900	17,800	7,900
San Francisco Bay	0	0	0	0
Central Coast	98	28	98	28
South Coast	69	51	69	51
Sacramento River	1,733	736	1,733	736
San Joaquin River	1,974	939	1,974	939
Tulare Lake	1,614	751	1,614	751
North Lahontan	271	154	271	154
South Lahontan	0	0	0	0
Colorado River	0	0	0	0
Total (rounded)	23,560	10,560	23,560	10,560

long-term unimpaired flow from the Department's Bulletin 1 was used. The estimated average unimpaired flow for the 1990-91 water years was used for the drought condition.

Instream Flows

Instream flow is the water maintained in a stream or river for instream beneficial uses such as fisheries, wildlife, aesthetics, recreation, and navigation. Instream flow is a major factor influencing the productivity and diversity of California's rivers and streams.

Instream flows may be established in a variety of ways—by agreements executed between DFG and a

water agency, by terms and conditions in a water right permit from SWRCB, by terms and conditions in a FERC hydropower license, by a court order, or by an agreement among interested parties. Required flows on most rivers vary by month and year type, with wet year requirements generally being higher than dry year requirements. Converting from net water use budgets used in prior editions of Bulletin 160 to the applied water budgets used in Bulletin 160-98 created a challenge in properly accounting for multiple instream flows within a river basin. Bulletin 160-98 used a simplified approach in which only the largest downstream flow requirement was included in the water budgets.



Part of Sespe Creek is included in the wild and scenic river system. The creek, located in Ventura County, is tributary to the Santa Clara River.

This simplified approach undercounts applied instream flow requirements on streams having multiple requirements. The Department is developing a new modeling approach for the next water plan update that will more accurately quantify applied instream flows.

Since the determination of 1990-level instream flow values used as base conditions in Bulletin 160-93, subsequent agreements or decisions have increased or added instream flow requirements for the Trinity River, Mokelumne River, Stanislaus River, Tuolumne River, Owens River, Putah Creek, and Mono Lake tributaries. In addition, ten new waterways have been added to the Bulletin 160-98 instream flow water budgets—the Mad River, Eel River, Russian River, Truckee River, East Walker River, Nacimiento River, San Joaquin River (at Vernalis), Walker Creek, Lagunitas Creek, and Piru Creek. The sidebar on American River environmental water use illustrates how environmental water demands are treated in Bulletin 160 water budgets.

Factors Affecting Future Instream Flows. It is difficult to forecast future regulatory actions or agreements that could change existing instream flow requirements. Bulletin 160-98 thus does not attempt to quantify the outcome of future regulatory or administrative actions. Factors likely to affect future flow

requirements include listings or potential listings of new fish species, habitat restoration programs, and programs to acquire water for environmental purposes.

Recent decisions on federal listing of coho salmon and steelhead trout (see Chapter 2) are likely to influence water management decisions affecting these species, but the specific actions will ultimately depend on the outcome of consultations, biological assessments, biological opinions, and habitat conservation plans. In 1997, the Governor's Executive Order W-159-97 created the Watershed Protection and Restoration Council. The council oversees State watershed protection and enhancement activities, including restoration of anadromous fish. One goal of this effort is to provide sufficient protection to coho, steelhead, and other anadromous salmonids to satisfy ESA requirements. Successful implementation of this program could lessen water supply impacts of salmonid listings.

Coho salmon are found in coastal streams and in large river systems such as the Klamath River and its tributaries. Some of the greatest potential for new water supply impacts could be on the Klamath River system (including its Trinity River tributary), where USFWS is finalizing instream flow studies for several salmonids. Steelhead populations are distributed

throughout coastal streams and rivers, and are also found in the Sacramento Valley. (Wild stocks of steelhead in the Sacramento River system are mostly confined to upper watershed tributaries such as Antelope, Deer, and Mill Creeks, and the Yuba River. The San Joaquin River system no longer supports a significant natural steelhead population—most steelhead found in the system are hatchery fish.) Data from the SWP and CVP pumping plants in the southern Delta indicate that most juvenile steelhead move through the Delta during the winter and early spring, when Bay-Delta Accord restrictions are already in place. Water supply impacts on coastal rivers and streams must be evaluated from a basin-specific standpoint.

The spring-run chinook salmon traditionally spawned in upper reaches of Central Valley rivers and their tributaries. Today, Deer, Mill, and Butte Creeks are considered crucial Sacramento River tributaries for spring-run spawning. Sustaining populations of spring-run are also found in Battle Creek, and the Feather and Yuba Rivers, although there are questions about the genetic integrity of these populations because of interbreeding between fall-run and spring-run salmon. Portions of Deer and Mill Creeks have been given special status by State legislation to help protect the fishery.

As described in Chapters 5 and 6, many habitat restoration programs are underway and substantial funding is available for restoration actions. Improvements such as facilitating fish passage, replenishing spawning gravel, and restoring shaded riverine habitat will help in efficient management of water used for environmental purposes. Specific benefits of habitat restoration will have to be evaluated on a watershed-by-watershed basis—it is not possible to quantify potential water supply implications of present and future habitat restoration actions at a statewide level. Examples of programs or projects now underway are described in later chapters.

The 1997 draft programmatic EIS for CVPIA implementation describes federal water acquisition alternatives for the AFRP. Table 4-19 shows the amounts proposed in alternative 4 of the draft PEIS. These flows represent the high end of potential federal water acquisition actions. Under USBR's assumptions for alternative 4, the instream flows are not allowed to be exported at the Delta. Quantification of alternative 4 flows was provided by PROSIM operations studies. The federal agencies' ability to acquire the water would be subject to their finding willing sellers.

In addition to water acquisition on major rivers

Environmental Water Use—An American River Example

As discussed in Chapter 3, the return flow from one water use can become the supply for the next downstream use. The applied water budgets in Bulletin 160-98 reflect the multiple uses which supplies in a river basin may have. Reapplication of flows in the American River for environmental purposes provides an illustration of how the Bulletin accounts for multiple uses in its water budgets.

The American River originates in the Sierra Nevada, flowing generally from east to west down through the foothills into the Sacramento Valley, ultimately reaching the Sacramento River and the Delta. The upper watershed of the American River consists of the north, middle and south forks. The mainstem, or Lower American River, begins near Folsom at the confluence of the north and south forks. Environmental water supplies are reapplied at several locations between the upper watershed and the Delta.

Wild and scenic environmental water demands exist on the American River's north fork (584 taf) and mainstem (20 taf). In Bulletin 160-98 water budgets, American River wild and scenic flows are classified as environmental water use on the demand side of the budget and as required environmental instream flow on the supply side of the budget. These

environmental demands are not consumptive; hence, the surface supplies are available for downstream use.

The American River has several instream flow requirements on its three forks as well as on its mainstem. For example, a 54 taf (75 cfs) requirement exists below Ralston Afterbay Dam on the middle fork and a 72 taf (100 cfs) requirement exists below Chili Bar Dam on the south fork. The river's largest instream flow requirement is on the mainstem below Nimbus Dam. This 234 taf requirement is the only American River instream flow requirement accounted for in the water budgets. As with wild and scenic demands, the American River instream flow requirement is shown as environmental water use on the demand side of the budget and as required environmental instream flow on the supply side of the budget. This environmental demand is not consumptive; therefore, the surface supply is available for downstream use.

Required instream flow in the American River is reapplied downstream to meet Delta outflow requirements. The Bulletin 160-98 water budgets classify this flow as reapplied surface water supply. About 70 percent of the Delta's 5.6 maf environmental demand (4.0 maf) is satisfied through reapplication of water released to meet environmental instream requirements in rivers tributary to the Delta.

TABLE 4-19

Proposed Instream Flows, CVPIA PEIS Alternative 4 (taf)

<i>Location</i>	<i>Region</i>	<i>Target</i>	<i>Average</i>
Merced River	San Joaquin River	200	194
Tuolumne River	San Joaquin River	200	197
Stanislaus River	San Joaquin River	200	194
Calaveras River	San Joaquin River	30	27
Mokelumne River	San Joaquin River	70	62
Yuba River	Sacramento River	100	87
Total		800	761

for the Alternative 4 instream flows shown in the table, the draft PEIS also proposes water acquisition on smaller Sacramento River tributaries such as Deer, Mill, and Battle Creeks. The draft PEIS does not quantify target flows and acquisitions for these smaller tributaries.

The public comment period on the draft CVPIA PEIS closed in April 1998 and USBR and USFWS expect to release a final PEIS in 1999, after the publication date of this Bulletin.

CVPIA authorizes DOI to acquire supplemental water from willing sellers. At this time, no long-term sources (e.g., long-term contracts for water transfers) have been established—water acquired has been purchased on a year-to-year basis. It is not possible to identify specifically how and where the supplemental water would be obtained in the future, or what other water demands might be reduced as a result of CVPIA water transfers. Chapter 6 provides more detail on how water marketing arrangements are treated in Bulletin 160 water budgets.

As discussed in Chapter 2, CVPIA also affects Trinity River instream flows, by requiring that Trinity River flows be maintained at not less than 340 taf/yr while USFWS conducts an instream flow study that was to be completed by 1996. USFWS's preliminary results suggest that instream flows of 592 taf/yr (weighted average of five water year types) may be proposed. USBR, USFWS, Trinity County, and the Hoopa Valley Tribe are preparing an EIR/EIS to evaluate impacts of the proposed flows. A draft EIR/EIS has not yet been released. Bulletin 160-98 uses the existing instream flow requirement of 340 taf/yr since a formal proposal for new Trinity River instream flows has not yet been released.

Instream Flow Summary. Tables 4-20 and 4-21 show instream flows used in Bulletin 160-98 water budgets by waterway and by hydrologic region. The drought year scenario shown in the tables represents

the minimum annual required flow volume. For average water years, the annual required flow volume is computed by combining the expected number of years in each year type (wet, above normal, normal, below normal, and/or dry, as specified in the existing agreement or order).

In water budget computations, the Department counts instream flows as depleted if the flows go directly to a salt sink, such as the ocean. In the Central Valley where some instream flows may reach the ocean, any depletions are counted toward required Delta outflow (see following section). This approach avoids counting depletions twice—once as instream flow and once as Delta outflow.

Bay-Delta Outflow

Environmental water use for Bay-Delta outflow is computed by using operations studies to quantify SWRCB Order WR 95-6 requirements. This section briefly describes the Delta's setting and some of its environmental resource issues. Readers interested in detailed descriptions of Delta hydrodynamics, facilities, and environmental resources may wish to review the extensive materials prepared by the Interagency Ecological Program, San Francisco Estuary Program, or CALFED program.

Setting. The Bay-Delta has two high tides and two low tides every day. An enormous volume of water (an average of about one-fourth of the estuary's total volume), moves in and out of the estuary with each tidal cycle. Tidal action and Delta outflow are two important physical processes which establish salinity gradients and carry sediments through the system. Tidal action and Delta outflow cause seaward-flowing fresh water from the rivers to mix with denser landward-flowing salt water from the ocean. The average tidal flow rate in the Delta is about 170,000 cfs, much greater than the average seaward flow of fresh water from rivers and streams.

CVPIA Anadromous Fish Restoration Program

One provision of CVPIA directed DOI to develop (by October 1995) and to implement a program “which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991”. (The San Joaquin River between Friant Dam and Mendota Pool is not covered by this goal.) In response to this provision, USFWS prepared a 1995 working paper listing many potential restoration actions (some involving instream flows, and some not) without regard to their reasonableness. Elements of that working paper were subsequently incorporated into a revised draft restoration plan prepared in May 1997. One function of the draft plan was to evaluate (at a programmatic level) the reasonableness of implementing potential restoration actions, given the authority and funding provided DOI by CVPIA. (For example, a potential restoration action that would involve modifying the diversion works of a local water agency would only be reasonable if the

local agency wished to participate with USBR or USFWS in the action.) The revised draft plan is scheduled to be followed by an implementation plan that would review priority actions to be taken in the next three to five years.

The CVPIA tools available to USFWS and USBR to carry out the AFRP include the 800 taf of project water dedicated for environmental purposes, the authority to acquire supplemental water to achieve AFRP goals, and the many physical habitat restoration measures required in the act (e.g., restoring spawning gravel, screening diversions, improving fish passage at Red Bluff Diversion Dam). The CVP dedicated water is only available to USFWS and USBR on CVP-controlled rivers below the major project dams. For other Central Valley waterways, the agencies are proposing to carry out a water acquisition program to buy water to meet AFRP needs. The quantity of water to be acquired is subject to available federal funding and the availability of water on the market. USBR’s 1997 draft CVPIA PEIS illustrates costs and impacts associated with different levels of supplemental water acquisition.



Fish species covered by the CVPIA's doubling goal are salmon, steelhead, striped bass, sturgeon, and American shad. This sturgeon was photographed at the Steinhart Aquarium.

TABLE 4-20
Instream Flow Requirements by Waterway (taf)^a

<i>River or Creek</i>	<i>1995</i>		<i>2020</i>	
	<i>Average</i>	<i>Drought</i>	<i>Average</i>	<i>Drought</i>
Klamath	833	833	833	833
Trinity	341	341	341	341
Mad	46	46	46	46
Eel	49	15	49	15
Russian	142	51	142	51
Lagunitas Creek	10	9	10	9
Walker Creek	6	0	6	0
Carmel	4	2	4	2
Nacimiento	16	7	16	7
Piru Creek	4	4	4	4
Clear Creek	25	25	25	25
Cache Creek	7	7	7	7
Putah Creek	22	22	22	22
Sacramento	1,945	1,702	1,945	1,702
Feather	880	588	880	588
Yuba	274	196	274	196
Bear	10	10	10	10
American	234	234	234	234
Mokelumne	158	84	158	84
Stanislaus	187	158	187	158
Tuolumne	214	94	214	94
Merced	79	67	79	67
San Joaquin	532	309	532	309
Truckee	70	70	70	70
East Walker	15	15	15	15
Mono tributaries	82	56	82	56
Owens	25	25	25	25
Total (rounded)	6,210	4,970	6,210	4,970

^a On streams with multiple instream requirements, only the largest downstream requirement is included in Bulletin 160-98 water budgets.

TABLE 4-21
Instream Flow Requirements by Hydrologic Region (taf)

<i>Region</i>	<i>1995</i>		<i>2020</i>	
	<i>Average</i>	<i>Drought</i>	<i>Average</i>	<i>Drought</i>
North Coast	1,410	1,285	1,410	1,285
San Francisco Bay	17	9	17	9
Central Coast	20	9	20	9
South Coast	4	4	4	4
Sacramento River	3,397	2,784	3,397	2,784
San Joaquin River	1,169	712	1,169	712
Tulare Lake	0	0	0	0
North Lahontan	85	84	85	84
South Lahontan	107	81	107	81
Colorado River	0	0	0	0
Total (rounded)	6,210	4,970	6,210	4,970

Recovery Efforts for Winter-Run Chinook Salmon

As indicated by the plot of winter-run salmon escapement, there has been a long-term decline in the species' population. The ultimate goal for recovery of winter-run salmon would be restoration of a self-sustaining, naturally spawning population. Two efforts being conducted to help achieve this goal are a captive broodstock program and an artificial propagation program. The purpose of the broodstock program is to maintain the genetic composition of the existing population, and that of the artificial propagation program is to stabilize and increase the naturally spawning population.

Discussions among State and federal agencies and stakeholder groups in 1991 and 1992 led to creation of a program to evaluate the feasibility of rearing Sacramento River winter-run fry in captivity, so that a broodstock would be available if wild winter-run fish were to disappear. (The population's small size makes it vulnerable to catastrophic loss of a year class, such as a loss that could be caused by a chemical spill in the vicinity of winter-run spawning areas. The captive broodstock would provide an alternative source of genetic material as insurance against such a loss.) Agencies participating in funding the program include USBR, USFWS, NOAA, the Department, and DFG. Rearing facilities were established at the University of California's Bodega Marine Laboratory and the California Academy of Sciences' Steinhart Aquarium. Juvenile fish, beginning with the 1991 year class, were delivered to the facilities in 1992. The parent broodstock were wild winter-run captured in the Sacramento River. Presently, fish from four year classes are being held at the facilities.

The artificial propagation program entails trapping known wild adult winter-run fish, spawning them in a controlled environment, and rearing the offspring for release back to the river system. As adults, the artificially propagated fish would return to winter-run spawning areas and commingle with wild winter-run. Artificial propagation activities were originally begun at USFWS's Coleman National Fish Hatchery on Battle Creek, but fish reared at Coleman imprinted on Battle Creek water and returned there to spawn,

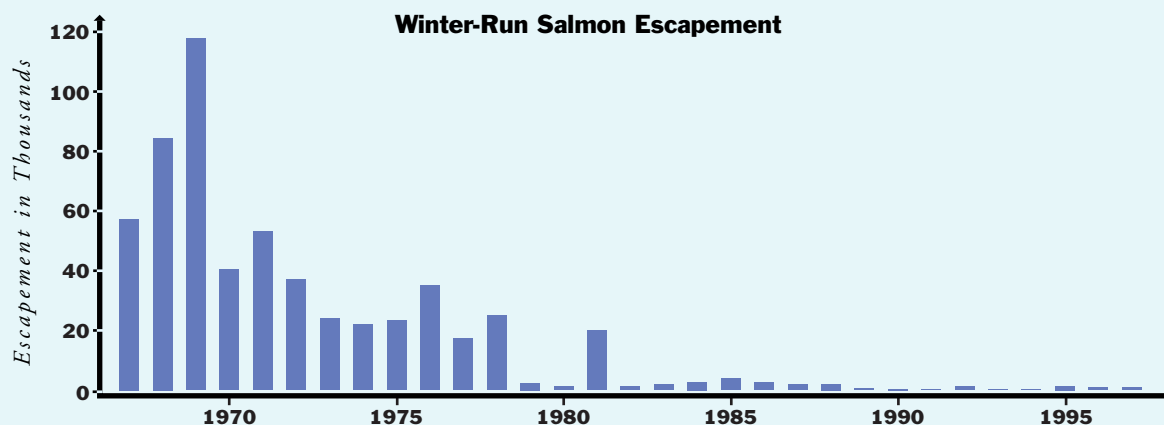


CVPIA directed USFWS to rehabilitate and expand Coleman National Fish Hatchery. The hatchery was constructed in 1942 to mitigate loss of Sacramento River salmon spawning areas due to construction of Shasta and Keswick Dams.

rather than going to the upper Sacramento River as desired. (There were also difficulties associated with distinguishing between winter-run and spring-run chinook, in selecting the fish to be propagated. Better genetic identification techniques have been developed to address this problem.)

The most recent development in the artificial propagation program was construction of an interim rearing facility, the Livingston Stone National Fish Hatchery, on the mainstem Sacramento River immediately downstream from Shasta Dam. This facility will allow the artificially spawned winter-run salmon to imprint on mainstem Sacramento River water, so that they will return to natural spawning grounds on the mainstem as adults. Water supply for the hatchery is provided via piping from the dam's penstocks. The hatchery is beginning operations in 1998.

Additional efforts to help recover winter-run chinook salmon, such as screening diversions and habitat improvement projects, are described in Chapter 8.



Three major components of Delta inflow include precipitation, inflow from the Sacramento and San Joaquin Rivers, and inflow from east side streams (including the Calaveras, Mokelumne and Cosumnes Rivers). Figure 4-11 shows annual inflow and outflow values for 1980-96. For this period, the average annual inflow to the Delta was 25.7 maf, more than 75 percent of which was contributed by the Sacramento and San Joaquin Rivers.

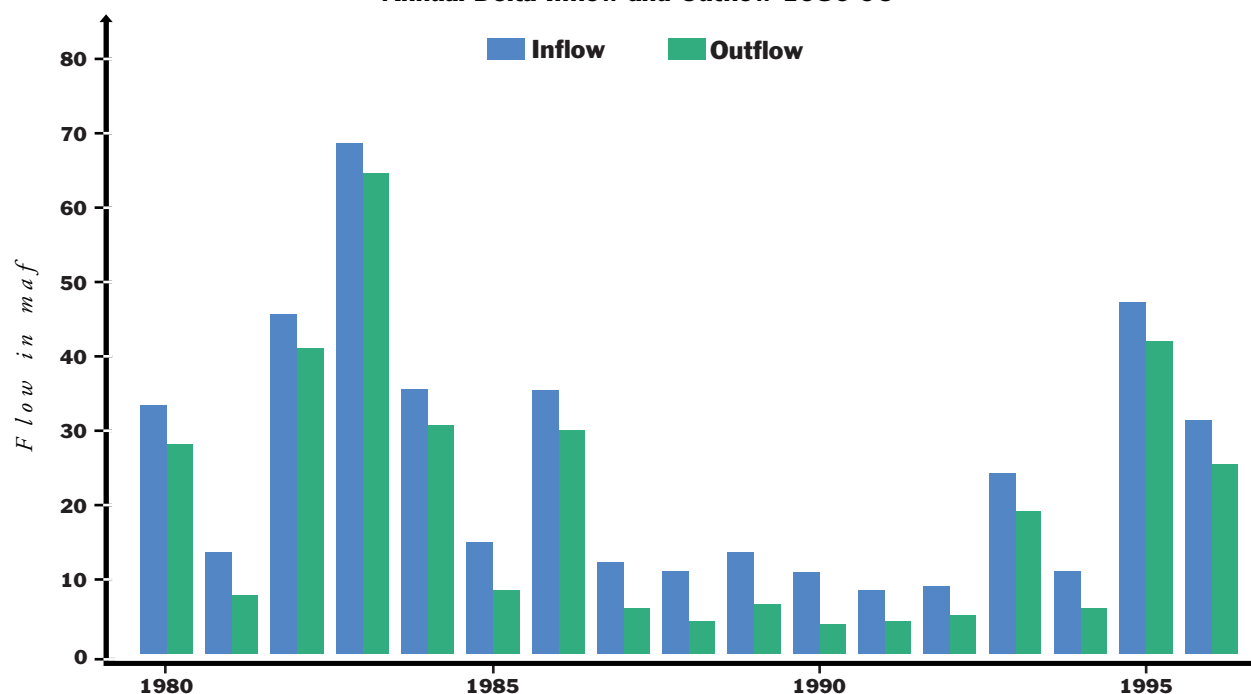
Delta outflow is the calculated amount of water flowing past Chipps Island at the western edge of the Delta into Suisun Bay. The magnitude of Delta outflow controls salt water intrusion from the ocean into the estuary. The magnitude of Delta outflow also influences the distribution of many estuarine fishes and invertebrates. Generally, the greater the outflow, the farther downstream estuarine fish and invertebrates occur. The relationship between Delta outflow and abundance of fish and invertebrates is much less clear. Some species, such as longfin smelt and juvenile splittail, show strong correlations between abundance and Delta outflow. The effects of outflow on species can vary depending on the time of year volume of outflow.

Suisun Bay, the first bay below the Delta, receives

fresh water inflow that contributes dissolved nutrients needed to support estuarine food chains. Adjacent to Suisun Bay is Suisun Marsh, which includes about 58,600 acres of diked managed wetlands, tidal marsh, and adjacent grasslands, 29,500 acres of waterways, and a buffer zone of 27,900 acres of varying land use. Suisun Marsh is one of the largest contiguous brackish water marshes in the United States. Nearly half of the waterfowl and shorebirds migrating on the Pacific flyway pass through the Bay-Delta each year, using the Suisun marsh and other Delta wetlands as feeding and resting stations.

Fresh water outflow from the Delta passes through Suisun Bay and through the Carquinez Straits, entering San Pablo Bay, and eventually reaching the Golden Gate. By comparison, there is limited fresh water outflow and tidal circulation at the southern end of San Francisco Bay. Fresh water outflow to the South Bay comes from local tributaries such as Coyote Creek and the Guadalupe River. San Pablo Bay and the South Bay both offer shallow water habitat. National wildlife refuges—the San Pablo Bay NWR and the San Francisco Bay NWR—occupy parts of the shoreline in these areas. See Figure 4-12 for a location map of the Bay-Delta.

FIGURE 4-11
Annual Delta Inflow and Outflow 1980-96^a



^a 1983 was the wettest year in Northern California in this century.

FIGURE 4-12
Bay-Delta Estuary





The Delta is characterized by miles of meandering waterways and leveed islands used mainly for agricultural purposes.

Delta Fish Species of Special Concern. About two-thirds of California's salmon migrate through the Delta, including species having commercial importance (fall-run chinook salmon), as well as listed or candidate species (winter-run chinook, spring-run chinook, and steelhead trout). Resident fish species of special concern include Delta smelt (listed as threatened under both the State and federal ESAs) and splittail (proposed for federal ESA listing). Habitat needs of anadromous and resident Delta species of special concern were reflected in actions taken in the Bay-Delta Accord and in SWRCB's Order WR 95-6. The accord's provisions for coordination of CVP and SWP opera-

tions in the Delta with the presence of fish species of concern have been reflected in actions by the CALFED Operations Group to reduce Delta exports at times when monitoring indicated that significant numbers of certain fish species were present in the southern Delta. Day-to-day management of CVP and SWP Delta operations under near real-time conditions requires extensive data collection and monitoring support. The Interagency Ecological Program, a cooperative effort of nine State and federal agencies (DWR, DFG, SWRCB, USBR, USFWS, EPA, NMFS, USACE, and USGS), acquires and disseminates near real-time fish distribution and abundance

Delta smelt, native to the Bay-Delta, have a one year life span and relatively low reproductive rate, making their population abundance sensitive to short-term habitat changes.



data used by the CALFED Operations Group.

Populations of native species of special concern are affected by a variety of factors, many of which are not related to Delta outflow. One nonflow factor now receiving more attention is competition from introduced aquatic species (see Chapter 2 for a description of the National Invasive Species Act of 1996). Introduction of non-native species into an ecosystem can alter the pre-existing balance achieved among the native species. Native species' populations can be reduced, for example, when introduced species out-compete the native species for food or otherwise alter the food chain, or when introduced species prey upon native species.

In the Bay-Delta, new introductions are occurring in a system that already has numerous introduced species. Researchers estimate that the Bay-Delta is now home to at least 150 introduced plant and animal species, some of which were introduced deliberately (planting of game fish species such as striped bass) and others whose arrival was accidental (discharge of invertebrates in ship ballast water). The Asian clam, for example, was first detected in the Bay in 1986 and has now become the most abundant mollusk in the northern part of the Bay. This clam is a voracious feeder on the phytoplankton which supports other aquatic species. The zebra mussel—which has caused millions of dollars of damage in the Great Lakes states—has not yet been detected in the Delta, but experts believe that it may be only a matter of time before the mussel arrives. Invasive plant species in the Delta include *Egeria densa* and *Arundo Donax* (giant reed). Hydrilla, another well-known invasive aquatic plant, is now found in Clear Lake in Northern California, and control measures are being taken to eradicate it there, to prevent its spread to Delta waterways.



The Asian clam was first detected in the San Francisco Bay in 1986. By the early 1990s, it was the most abundant mollusk in the northern part of the Bay.



Much of the land in the Suisun Marsh is owned and managed by private gun clubs for duck hunting. DFG manages a wildlife area on Grizzly Island.

Quantifying Delta Outflow Requirements.

SWRCB Order WR 95-6 established numerical objectives for salinity, river flows, export limits, and Delta outflow. DWRSIM operations studies were used to translate these numerical objectives into Delta outflow requirements for average and drought year scenarios. The studies computed outflow requirements of approximately 5.6 maf in average years and 4.0 maf in drought years.

Wetlands

The wetlands component of environmental water use is based on water use at freshwater managed wetlands, such as federal national wildlife refuges and State wildlife management areas. The following text reviews the status of wetland acreage in California and wetland management programs, then discusses quantification of water demands and supplies for wetlands.

In general, wetlands can be divided into saltwater and brackish water marshes (usually located in coastal areas) and freshwater wetlands (generally located in inland areas). Five areas of California contain the largest remaining wetlands acreage in the State—the Central Valley, Humboldt Bay, San Francisco Bay, Suisun Marsh, and Klamath Basin. The majority of the State's wetland protection and restoration efforts are occurring in these areas. Nontidal wetlands usually depend on a supplemental water supply, and protecting or restoring them may create demands for freshwater supplies.

Wetlands Policies and Programs. Many programs and policies have been adopted by federal, State and regional agencies and private entities to protect and restore wetlands in California. Several of the more re-



California is a wintertime destination for migratory waterfowl on the Pacific flyway. Managed wetlands provide feeding, resting, and overwintering sites for the waterfowl.

cent wetland programs and policies are discussed below.

Ecosystem restoration is a large part of the CALFED program. CALFED's draft ERP plan proposes habitat restoration goals that include creating 64,000 acres of seasonal and perennial wetlands and 2,000 acres of riparian habitat, returning 37,000 to 57,000 acres to tidal action and enhancing 8,000 acres of existing seasonal wetlands. About 1,700 acres of wetland restoration projects were funded under the accord's

Category III program in 1995 and 1996.

CVPIA required DOI to provide water supplies to the wetlands areas shown in Table 4-22. The Sacramento Valley refuges were to be provided with water supplies specified in a 1989 refuge water supply investigation prepared by USBR, and the San Joaquin Valley wetlands areas with supplies specified in USBR's San Joaquin Basin Action Plan/Kesterson Mitigation Action Plan. This water supply was to be provided in two increments—the first corresponding to the exist-

California Wetlands Conservation Policy

In 1993, a California wetlands conservation policy was established. The goals of the policy were to establish a framework and a strategy that would:

- Ensure no overall net loss and achieve a long-term net gain in the quantity, quality, and permanence of wetlands acreage and values in California in a manner that fosters creativity, stewardship, and respect for private property.
- Reduce procedural complexity in the administration of State and federal wetlands conservation programs.
- Encourage partnerships to make landowner incentive

programs and cooperative planning efforts the primary focus of wetlands conservation and restoration.

The policy recommended completion of a statewide inventory of wetlands which would lead to the establishment of a formal wetland acreage goal. This inventory is in progress. The Resources Agency expects these policies to result in improved status for 30 to 50 percent of the State's wetlands by the year 2010. Based on an estimate of 450,000 acres of existing wetlands in the State, as much as 225,000 acres of wetland could be improved, restored or protected.

TABLE 4-22
CVPIA Refuge Water Supplies^a (taf)

<i>Refuge</i>	<i>Level 2 Supply at Refuge Boundary</i>	<i>Level 4 Supply at Refuge Boundary</i>
Sacramento Valley Refuges		
Sacramento National Wildlife Refuge	46.4	50.0
Delevan National Wildlife Refuge	20.9	30.0
Colusa National Wildlife Refuge	25.0	25.0
Sutter National Wildlife Refuge	23.5	30.0
Gray Lodge Wildlife Management Area	35.4	44.0
Total for Sacramento Valley Refuges	151.2	179.0
San Joaquin Valley Refuges		
San Luis National Wildlife Refuge	19.0	19.0
Kesterson National Wildlife Refuge ^b	10.0	10.0
Volta Wildlife Management Area	13.0	16.0
Los Banos Wildlife Management Area	16.6	25.5
San Joaquin Basin Action Lands		
Freitas	5.3	5.3
West Gallo	10.8	10.8
Salt Slough	6.7	10.0
China Island	7.0	10.5
Grasslands Resource Conservation District	125.0	180.0
Mendota Wildlife Management Area	27.6	29.7
Merced National Wildlife Refuge	15.0	16.0
East Gallo	8.9	13.3
Kern National Wildlife Refuge	9.9	25.0
Pixley National Wildlife Refuge	1.3	6.0
Total for San Joaquin Valley Refuges	276.1	377.1
Total for all Refuges	427.3	556.1

^a Table is excerpted from 1997 draft CVPIA PEIS.

^b Kesterson NWR was merged with San Luis NWR subsequent to CVPIA enactment.

ing average annual deliveries that the wetlands had been receiving from drain water and other sources, and the second corresponding to the ultimate or optimum management levels of the wetlands. The first increment of water supply (Level 2) was to be provided by reallocation of CVP supplies. The second increment (Level 4) was to be acquired through purchases from willing sellers. DOI was to acquire all of the second increment of supply by 2002. USBR has operated the CVP to provide the Level 2 supplies, and has been making year-to-year short-term water purchases for the increments of Level 4 supply. USBR and USFWS have been studying conveyance alternatives (and ground-water extraction, in addition to surface water supply alternatives) associated with making these increased supplies available to the refuges.

CVPIA also required DOI to prepare a report by September 1997 to investigate methods of improving water supplies in the Central Valley for existing private wetlands and for 120,000 acres of new wetlands. The 120,000 acres came from wetland restoration ob-

jectives of a Central Valley Habitat Joint Venture report. USFWS's report is currently in preparation.

Additionally, the act required that financial incentives be made available to farmers within the CVP service area for flooding agricultural lands to provide waterfowl habitat. The incentives include cost-sharing for water purchases, pumping costs, facility construction (e.g., water control structures), and upgrades or maintenance to existing facilities. CVPIA caps the funding for this program at \$2 million per year and the program terminates in 2002.

In 1986, the North American Waterfowl Management Plan was signed by the United States and Canada. The plan was updated in 1996 and Mexico became a signatory. NAWMP provides a framework for waterfowl management in North America through 2010; it includes numerical goals for waterfowl populations and for habitat protection, restoration, and enhancement. Implementing NAWMP is the responsibility of joint ventures in which governmental agencies and private organizations pool resources to address habitat needs.

There are four NAWMP joint ventures covering parts of California. A fifth joint venture is being considered in Southern California. The four existing joint ventures are described below.

The Central Valley Habitat Joint Venture, established in 1988, was the first California joint venture. CVHJV adopted six goals for the Central Valley:

- Protect 80,000 acres of wetlands through fee acquisition or conservation easement.
- Restore (and protect) 120,000 acres of former wetlands.
- Enhance 291,555 acres of existing wetlands.
- Enhance water-based habitat on 443,000 acres of private agricultural land.
- Secure 402,450 af of water for 15 refuges in the Central Valley.
- Secure CVP preference power for public and private lands dedicated to wetland management (i.e., provide access to low-cost power generated at CVP facilities).

In 1990, the Legislature authorized the Inland Wetlands Conservation Program administered by the Wildlife Conservation Board. This program carries out some CVHJV objectives by administering a \$2 million per year program to acquire wetland habitat.

The Pacific Coast Joint Venture encompasses coastal wetlands, major rivers, and adjacent uplands from northern British Columbia to the northern edge of San Francisco Bay. In California, there are two focus areas with strategic plans outlining specific target areas and acreage objectives. Almost all the wetlands are coastal projects with little or no freshwater requirements. Objectives for the northern focus area (Del Norte and Humboldt counties) are:

- Maintain 22,000 acres of seasonal wet pasture in agricultural usage compatible with water-associated wildlife.
- Permanently protect an additional 10,500 acres of key wetlands through easements or fee acquisitions.
- Protect, restore, and enhance 10,100 acres of wetlands on existing public lands.
- Assist landowners to protect, enhance, and restore 5,000 acres through cooperative projects.

Objectives of the southern focus area (Mendocino, Sonoma, and Marin Counties excepting watersheds draining to San Francisco Bay) are:

- Permanently secure through fee acquisition or easements an additional 20,000 acres of coastal and interior wetlands, riparian habitats, and associated uplands.
- Restore 3,500 acres of reclaimed coastal and interior wetlands on private and public lands.

- Enhance 5,500 acres of coastal and interior wetlands and riparian habitats on public and private lands.

Approximately half of the acreage in the southern focus area is inland (nontidal) habitat requiring fresh water.

The Intermountain West Joint Venture encompasses parts of Canada and Mexico and all or part of eleven western states, including eastern California. The California action group has completed a working agreement and drafted plans for six focus areas. Acreage goals for acquisition, restoration, and enhancement have not been established.

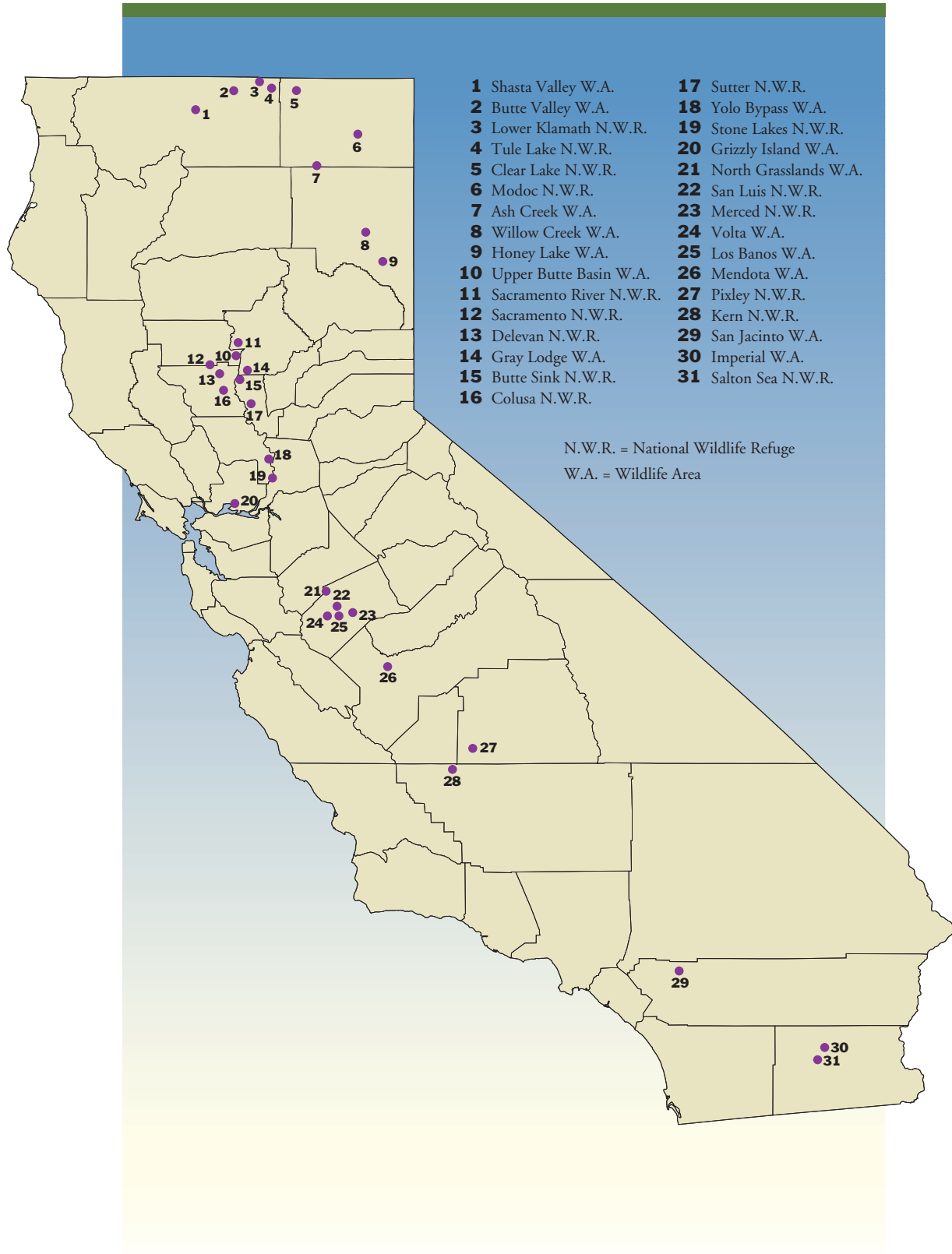
The San Francisco Bay Joint Venture was established in 1995. Its management board is drafting an implementation strategy. Formal acreage goals and timelines for acquisition and restoration projects will be established. It is expected that many of the areas protected or restored by the SFBJV will be tidal areas with little or no fresh water requirement.

Refuge Water Supply Conservation Programs.

In the spring of 1997, a refuge water supply interagency coordinated program task force was formed as an outgrowth of discussions in CALFED and CVPIA programs regarding the need to have best management practices for water conservation on wildlife refuges. The goal of the task force is to develop a common methodology for water management planning, including water conservation actions, for the federal, State, and private refuges covered in CVPIA's refuge water supply provisions. A draft document containing BMPs or efficient water use guidelines for the refuges is scheduled to be released for public review in 1998.

Wetlands Water Use. Bulletin 160-98 quantifies applied water needs only for managed wetlands, because other wetlands types such as vernal pools or coastal wetlands use naturally-occurring water supply (precipitation or tidal action). Managed wetlands are defined for the Bulletin as impounded freshwater and nontidal brackish water wetlands. Managed wetlands may be State and federal wildlife areas or refuges, private wetland preserves owned by nonprofit organizations, private duck clubs, or privately owned agricultural lands flooded for cultural practices such as rice straw decomposition. Figure 4-13 shows California's publicly owned wetlands. Some of the largest concentrations of privately owned wetlands are the duck clubs in the Suisun Marsh and the flooded rice fields in the Sacramento Valley. (Acreage of rice fields flooded to enhance decomposition of stubble remaining after harvest and to provide habitat for

FIGURE 4-13
Publicly-Owned Fresh Water Wetlands



overwintering waterfowl was identified by Department land use surveys.)

State and federal wetlands in the Central Valley are normally managed to support several types of wild-life use areas—permanent marsh, seasonal marsh, irrigated waterfowl food crops (such as millet, rice, or smartweed), and non-irrigated uplands. Each has different applied water requirements, as indicated in Table 4-23, which shows typical ranges for Central Valley wetlands. Table 4-24 shows wetlands water demands by region.

TABLE 4-23

**Ranges of Applied Water on Central Valley
Managed Wetlands (af/acre/year)**

<i>Type of Use</i>	<i>Applied Water</i>
Permanent marsh	5-10
Seasonal marsh	2-10
Irrigated waterfowl food crops	1-4

TABLE 4-24

Wetlands Water Use by Hydrologic Region (taf)

<i>Region</i>	<i>1995</i>		<i>2020</i>	
	<i>Average</i>	<i>Drought</i>	<i>Average</i>	<i>Drought</i>
North Coast	325	325	325	325
San Francisco Bay	160	160	160	160
Central Coast	0	0	0	0
South Coast	27	27	31	31
Sacramento River	632	632	632	632
San Joaquin River	230	230	240	240
Tulare Lake	50	50	53	53
North Lahontan	18	18	18	18
South Lahontan	0	0	0	0
Colorado River	39	38	44	43
Total (rounded)	1,480	1,480	1,500	1,500

TABLE 4-25

Applied Environmental Water Use by Hydrologic Region (taf)

<i>Region</i>	<i>1995</i>		<i>2020</i>	
	<i>Average</i>	<i>Drought</i>	<i>Average</i>	<i>Drought</i>
North Coast	19,544	9,518	19,545	9,518
San Francisco Bay	5,762	4,294	5,762	4,294
Central Coast	118	37	118	37
South Coast	100	82	104	86
Sacramento River	5,833	4,223	5,839	4,225
San Joaquin River	3,396	1,904	3,411	1,919
Tulare Lake	1,672	809	1,676	813
North Lahontan	374	256	374	256
South Lahontan	107	81	107	81
Colorado River	39	38	44	43
Total (rounded)	36,940	21,240	36,980	21,270

Summary of Environmental Water Use

Table 4-25 shows base 1995 and forecasted 2020 environmental water use by hydrologic region. The large values in the North Coast Region illustrate the magnitude of demands for wild and scenic rivers in comparison to other environmental water demands.

Water Use Summary by Hydrologic Region

Tables 4-26 and 4-27 summarize California applied water use by hydrologic region. The tables combine the urban, agricultural, and environmental water use described in this chapter. These demands, together with the water supply information presented in Chapter 3, are used to prepare the statewide water balance shown at the beginning of Chapter 6 and the regional water balances shown in Chapters 7-9.

TABLE 4-26
California Average Year Water Use by Hydrologic Region (taf)

Region	1995			2020				
	Urban	Agricultural	Environmental	Total (rounded)	Urban	Agricultural	Environmental	Total (rounded)
North Coast	169	894	19,544	20,610	201	927	19,545	20,670
San Francisco Bay	1,255	98	5,762	7,110	1,317	98	5,762	7,180
Central Coast	286	1,192	118	1,600	379	1,127	118	1,620
South Coast	4,340	784	100	5,220	5,519	462	104	6,080
Sacramento River	766	8,065	5,833	14,660	1,139	7,939	5,839	14,920
San Joaquin River	574	7,027	3,396	11,000	954	6,450	3,411	10,820
Tulare Lake	690	10,736	1,672	13,100	1,099	10,123	1,676	12,900
North Lahontan	39	530	374	940	50	536	374	960
South Lahontan	238	332	107	680	619	257	107	980
Colorado River	418	4,118	39	4,570	740	3,583	44	4,370
Total (rounded)	8,770	33,780	36,940	79,490	12,020	31,500	36,980	80,500

TABLE 4-27
California Drought Year Water Use by Hydrologic Region (taf)

Region	1995			2020				
	Urban	Agricultural	Environmental	Total (rounded)	Urban	Agricultural	Environmental	Total (rounded)
North Coast	177	973	9,518	10,670	212	1,011	9,518	10,740
San Francisco Bay	1,358	108	4,294	5,760	1,428	108	4,294	5,830
Central Coast	294	1,279	37	1,610	391	1,223	37	1,650
South Coast	4,382	820	82	5,280	5,612	484	86	6,180
Sacramento River	830	9,054	4,223	14,110	1,236	8,822	4,225	14,280
San Joaquin River	583	7,244	1,904	9,730	970	6,719	1,919	9,610
Tulare Lake	690	10,026	809	11,530	1,099	9,532	813	11,440
North Lahontan	40	584	256	880	51	594	256	900
South Lahontan	238	332	81	650	619	257	81	960
Colorado River	418	4,118	38	4,570	740	3,583	43	4,370
Total (rounded)	9,010	34,540	21,240	64,790	12,360	32,330	21,270	65,960

